ROYAL INSTITUTE
OF TECHNOLOGY

Studies on Image Control for Better Reproduction in Offset

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Thesis for the degree of Licentiate of Technology to be presented with due permission for public examination and criticism in E2, KTH, Lindstedtsvägen 3 at the Royal Institute of Technology, KTH,
on 15 december 2006 at 13.00.

TRITA-CSC-A 2006 : 27.
ISSN-1653-5723
ISRN-KTH/CSC/A--06/27--SE
ISBN 91-7178-524-8
ISBN 978-91-7178-524-4

Contents

Preface

This thesis consists of the seven papers, listed below, which are referred to in the text by their Roman numerals.

Paper I - Enoksson Emmi
"Image Classification and Optimized Image Reproduction"
TAGA 2003, Montreal, Canada, Taga Proceedings 2003, pp 33-36

Paper II - Enoksson Emmi, Aviander Per
"The characterization of input devices by luminance and chrominance"
VI.Polygraficky seminar, 2003, Pardubice, Czech Republic, 10 pages

Paper III - Enoksson Emmi
"Image Reproduction Practices"
TAGA 2004, San Antonio, USA, Taga Proceedings 2004, pp 318-331

Paper IV - Enoksson Emmi
"Digital Test Form for ICC-profiles"
TAGA 2005, Toronto, Canada, Taga Proceedings 2005, pp 454-473

Paper V - Enoksson Emmi, Aviander Per
"Demand specifications for controlled color reproduction"
VII.Polygraficky seminar, 2005, Pardubice, Czech Republic, 11 pages

Paper VI - Enoksson Emmi, Bjurstedt Anders
"Compensation by black - a new separation?"
TAGA 2006, Vancouver, Canada, Taga Proceedings 2006, pp 193-217

Paper VII - Nordstedt Sofia, Kolseth Petter, Enoksson Emmi
"Using Gray-Balance Control in Press Calibration for Robust ICC Color Management in Sheet-Fed Offset"
TAGA 2004, San Antonio, USA, Taga Proceedings 2004, pp 1-20

Abstract

This research work has focused on studies of image control for better reproduction in offset and has been applied practically. This research work has resulted in a survey of color management knowledge, a communication list concerning ICC profiles, an educational kit, a proposal for a new terminology and a patent concerning image adaptation.

The work is divided into following three areas:

1) image classification

A better understanding of image processing can avoid misunderstandings in the print and leading to more satisfied customers. To achieve optimal print quality for different images, it is important to adapt the prepress settings to the image category. Images can be divided into different categories depending on their image content, key information and tone distribution.

Trials have been carried out in which the IT.8 test chart has been adapted to different image categories. The results of the image adaptation suggest that an adjustment only to low-key images (dark images) is sufficient, as even normal-key images then show a better similarity to the original image. The low-key image showed more details in dark areas.

2) color separation

Two studies has been carried out. The purpose has been to investigate the knowledge level in color separation, the use of ICC-profiles and the understanding of color management in various printing houses in Sweden. This was done to identify and suggest new applications and suggested actions. These studies indicate that there is a serious problem in the graphic arts industry. The problem is that there is both an insufficient knowledge of color management and a lack of communication. There is a lack of competence and a lack of literature and instructions which can help printers to better understand the technology, and communication suffers through a lack of a common language.

3) suggested actions and the development of tools

Terminology simplification is crucial for the users. A new term for separation “Compensation by Black”, CB, has been suggested. A single term should make it easier for the users to understand and use the different settings which impact the image reproduction. A new tool/kit for the evaluation of ICC-profiles has been created. The goal of this educational kit is to facilitate and exemplify the practical understanding of profiles and their use for the users.

Keywords

Images, offset, printing, ICC, color, gamut, profile, calibration, separation, GCR, UCR, characterization.

Acknowledgements

I would like to thank the Swedish Print Technology Research program T2F (www.t2f.nu) for supporting me in this work.

Prof. Nils Enlund, the Royal Institute of Technology, is thanked for comments and support.

I would also like to thank Dr Jan-Erik Nordström, Stora Enso Kvarnsveden Mill, Sweden, for constructive comments on all my papers.

Many thanks also to Anders Mohlin and Björn Olsson for their comments.

My son Mattias Enoksson is thanked for help with the translations.

The greatest thanks go to my husband Göran Enoksson for his support and patience during my work.

1 Introduction

The production of a printed product involves three stages: prepress, the printing process (press) itself, and finishing (postpress), see figure 1. These separate production stages are connected by a flow of materials, such as printing plates between prepress and press and printed sheets between press and postpress. The interconnection between the production stages has become increasingly marked by the data flow. Information is exchanged both for the actual production of special printed products and for the organization of the business and production cycles. Information and data are an essential requirement for the optimal and reliable functioning of individual production processes and equipment, and for an efficient, high-quality and economic production. (Kipphan, 2001)

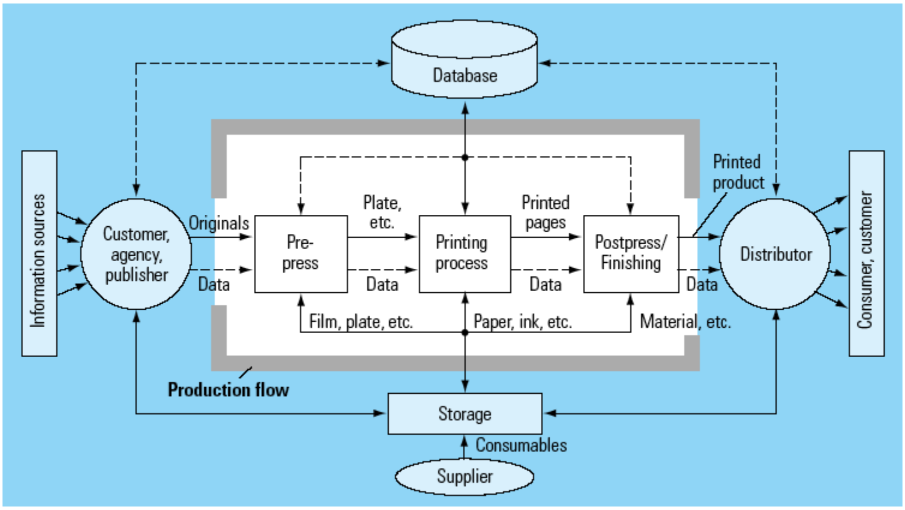


Figure 1: Production flow, material and data flow for print media production (Kipphan, 2001).

This thesis focuses on image reproduction as is a part of the prepress process. Prepress includes all the steps which are carried out before the actual printing, where information is transferred onto paper or another substrate.

Today, text, images and layout can be prepared either by customers, the author, or the agency. This division of work is also applicable to the jobs carried out within a printshop with a prepress stage included. The basic stage in the creation of a digital page is shown in figure 2.

* main terms are explained in the Appendix

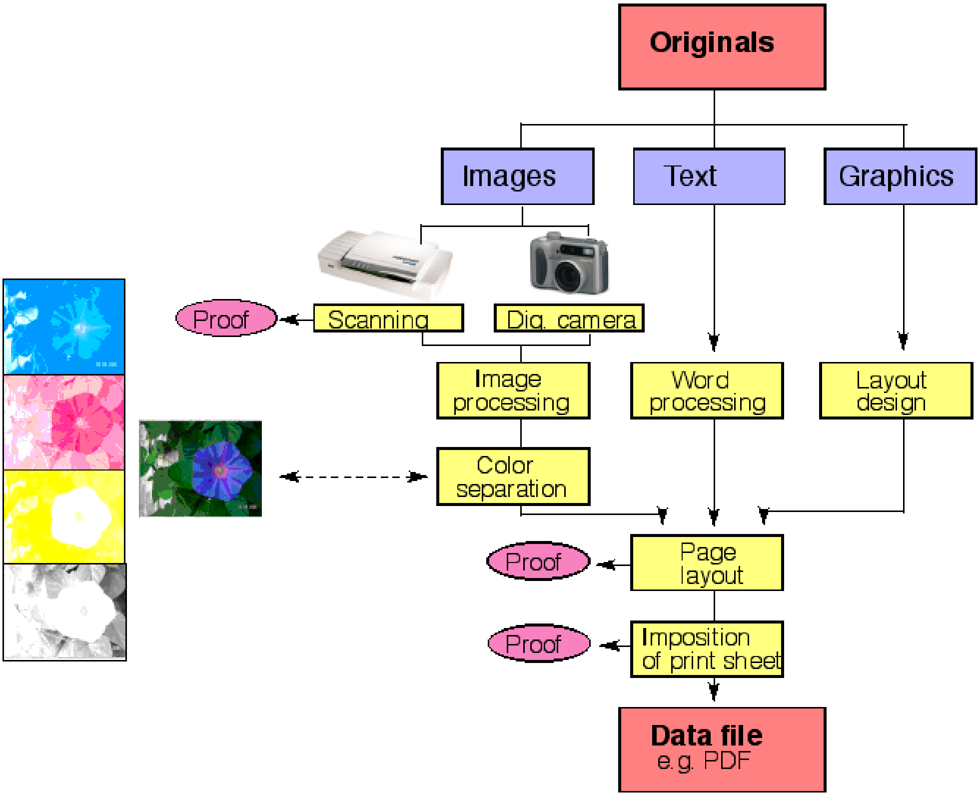


Figure 2: The purpose of the page layout is to create a digital page from individual elements such as text, graphics, and images, which contains all the information relevant for further processing (based on Kipphan, 2001).

1.1 Color rendering

It is important to achieve the best possible reproduction of an image in printing. The demand for high quality is crucial for both print customers and the final users. There are various types of equipment (i.e.printers) and many applications (i.e.image processing, profile making) on the market. Each type of equipment and each application has its own characteristics and algorithms and works in its own way. The variety of, for example, proof printers and digital test printing equipment of varying quality has also increased dramatically. Not only do these types of equipment work in different ways, but they also render colors in different ways, and this generates problems. If one scans an image using two different scanners, one will usually obtain two different results. If one prints using two different printers or printing machines, one will also obtain different results. The first problem/phenomenon is related to the device-dependent additive color system* and the second to the device-dependent subtractive color system*. The terms additive and subtractive are used to differentiate between the mixing of colored lights and the mixing of colorants (Billmeyer, Saltzman, 1981). The fact that two devices are based on the same color model and color system does not necessarily mean that they will render color in the same way. Different monitors (even of the same model and company) that are RGB*-based (Red, Green, Blue) often render colors in different ways.

Therefore, the equipment must be under strict control, i.e. correctly adjusted and calibrated* in order to show colors correctly.

To achieve a print result with predictable color is thus complicated. A great help is “color management which attempts to make color more predictable within the limitations of the devices in use” (Adams, Weisberg, 2000). Color management translates color between devices using a device-independent profile connection space and standard profiles for each device. A profile characterizes a device´s color reproduction capabilities (Adams, Weisberg, 2000). The color units (for example scanner, display, printer) are characterized in a common general format, ICC (International Color Consortium*). Through the ICC-format, ICC-profile*, various colors and hues can be interpreted in a similar fashion regardless of the platform and application (computer type, system construction and prep-press programs), see figures 3 and 4. The ICC-format enables the color space* of a color unit to be determined from a large amount of measured values, and thus enables, for example, optimization of printing simulations, by using color engines, color profiling. Before the ICC-format was introduced, the color separation* was performed directly in image scanners or in imaging applications (i. e. Adobe Photoshop), where the color was mainly visually evaluated.

* main terms are explained in the Appendix

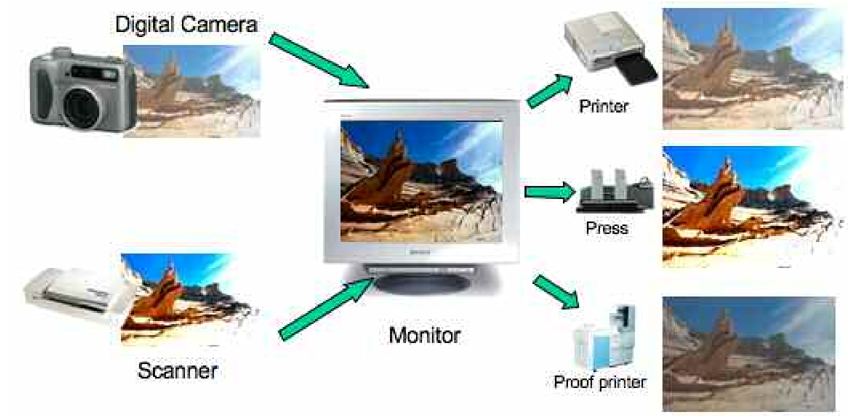


Figure 3: An example of an image reproduction without color management.

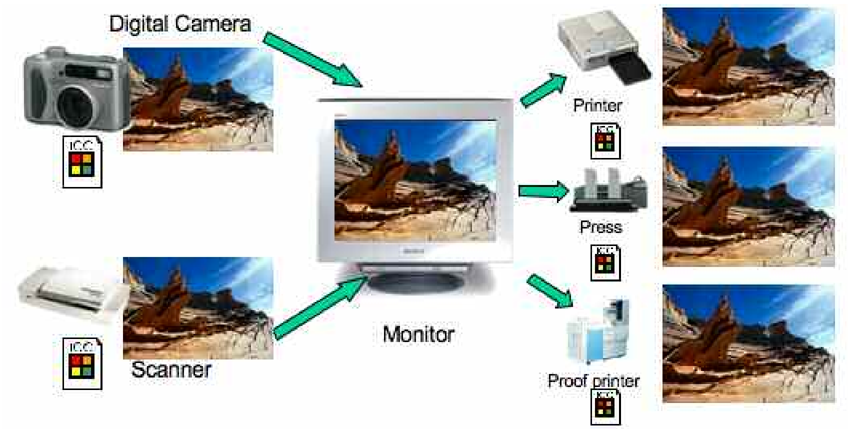


Figure 4: An example of an image reproduction with color management. The ICC profiles help steer the color.

1.2 Color Management System

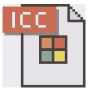
A color management system (CMS) is a collection of color management software tools used to try to make color device-independent. Ideally, the colors on your monitor should accurately represent both the colors in a scanned image and the colors you will see on the final output. A CMS maps the colors in the color gamut* of one device into a device-independent color space, and then transforms those colors to the color gamut of another device. (www.adobe.com, 2006)

Color management operations can be described in terms of the three “C”s: calibration, characterization and conversion. Calibration involves deciding on the paper/ink type. Characterization involves building profiles. Conversion occurs when we use profiles to transform image data from RGB* to CMYK*. (Sharma, 2004)

1.2.1 ICC - International Color Consortium

The ICC was formed in 1993 to seek to establish specifications and guidelines for the manufacturers and developers of software, equipment, and producers in terms of color management systems (Field, 2004). The main document produced by the ICC is The ICC Profile Format specification, which describes an open profile format that all vendors can use . By defining a format that allowed consumers to mix and match profiles created by different vendors, the ICC standardized the concept of profile-based color management (Fraser, Murphy, Bunting, 2003).

The ICC has done a important job within standardization, to promote the use and adoption of open, vendor-neutral, cross-platform color management systems. The ICC is actively working to make the ICC specification more useful to the various constituencies that have adopted ICC workflows. The ICC encourages vendors to support the ICC profile format and the workflows required to use ICC profiles.



1.2.1.1 ICC-profiles

An ICC-profile is a file of data describing the color characteristics of a device such as a scanner, monitor, or printer. The primary purpose of this file is for use in color management software to maintain color consistency in imagery viewed, displayed or printed on various devices. The file contains descriptions of specific devices and their settings, together with numerical data describing how to transform the color values which are to be displayed or printed on the device. The numerical data includes matrices and tables that a color management module (CMM) uses to convert that device’s color data to a common color space, defined by the ICC and called the profile connection space (PCS), and back to the device’s color space. (Wallner, 2000)

* main terms are explained in the Appendix

1.2.1.2 CMM

The Color Management Module is the software “engine” that does the job of converting the RGB or CMYK values using the color data in the profiles. A profile can not contain the PCS definition for every possible combination of RGB or CMYK numbers so the CMM has to calculate the intermediate values. The CMM provides the method which the color management system can use to convert values from source color space to the PCS and from the PCS to any destination space. (Fraser, Murphy, Bunting, 2003)

1.2.1.3 PCS - Profile Connection Space

Color management uses an ICC profile to translate the image data to PCS, see figure 5. A profile contains two set of values, RGB or CMYK device control values, and the corresponding CIE XYZ* or CIE LAB* (Fraser, Murphy, Bunting, 2003). The standard color space is the interface which provides an unambiguous connection between the input and output profiles, as illustrated in figure 4. It allows the profile transforms for input, display, and output devices to be decoupled so that they can be produced independently. A well-defined PCS provides the common interface for the individual device profiles. It is the virtual destination for input transforms and the virtual source for output transforms. If the input and output transforms are based on the same PCS definition, even though they are created independently, they can be paired arbitrarily at run time by the color-management engine (CMM) and will yield consistent and predictable results when applied to color values (www.color.org).

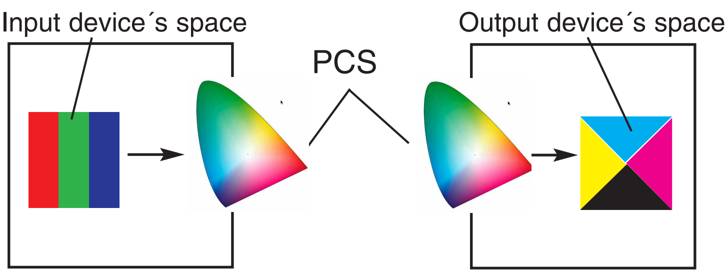


Figure 5: A profile contains two set of values, RGB or CMYK device control values, and the corresponding CIE XYZ or CIE LAB values that they produce.(Fraser, Murphy, Bunting, 2003).

The profile connection space makes it possible to give a color an unambiguous numerical value in CIE XYZ or CIE LAB that does not depend on the quirks of the various devices used to reproduce that color, but instead defines the color it is actually seen (Fraser, Murphy, Bunting, 2003).

Converting colors always requires two profiles, a source and a destination. The source profile tells the CMS (Color Management System) what colors the document contains, and the destination profile tells the CMS what new set of control signals is required to reproduce these colors on the destination device.

1.2.2 Successful Color Management (CM)

Based on the survey (Marin, 2004), the following points should be kept in mind to be successful when implementing color management:

- *implement process controls in your organization*
  Process controls are the key factors for successful CM. A process that is not consistent and repeatable will render a color profile useless.
- *the CM process requires training*
- *know that color management is a process*
  Color management is not just a software application, a measuring device, and a profile.
- *give it time*

* main terms are explained in the Appendix

2 The main objectives of this work

The purpose of this work has been to contribute to the scientific and practical knowledge concerning categorization of images and color separation.

The work is divided into the following three areas:

1) image classification

- the purpose has been to investigate methods for categorizing and classifying images in order to make it easier to understand image processing. A better understanding of image processing can avoid misunderstandings in the print and lead ultimately to more satisfied customers.

2) color separation

- the purpose has been to investigate the knowledge level with regard to color separation, ICC-profiles and color management in various printing houses in Sweden, in order to find new applications and implement suggested action.

3) suggested actions and the development of tools

- the purpose has been to create tools to facilitate the understanding of color management for the users and thereby a more optimized printing process with better printing results.

The papers which form the thesis are appended at the end of this thesis.

2.1 Delimitation

The study was focused on the lithographic offset process, especially sheet-fed offset. Test printing was carried out in a laboratory offset press, Heidelberg Speedmaster 74-6.

3 Methodology

This work is based on theoretical research and practical activities and is divided into the following three areas:

1) image classification
2) color separation
3) suggested actions and the development of tools

Image classification started with literature studies. Practical exercises have been performed with different image categories, where the goal was to identify borders between the images. The luminance of the images was studied in the Adobe Photoshop and Matlab software. Test prints have been prepared on a sheet-offset press Heidelberg Speedmaster 74-6. Subsequently, the image category borders were used to create an IT.8 test chart for the print.

The IT.8 test chart has also been adjusted for scanners. The aim here was to see whether it is possible to partially adjust the IT.8 test chart for scanners to suit one´s needs. The work was started by first comparing the different IT.8 test charts for scanners available on the market at the time, with respect to how the different test charts correlated to each other, to the ISO- standard and to the different RGB color working spaces* used in imaging applications.

Color separation started with two investigations carried out between 2000 and 2004. The case studies are based on semi-structured interviews. Direct contact (e.g. e-mail, phone and site visits) was established with printing facilities in order to assess the level of knowledge concerning color separation and the use of ICC-profiles* in the graphic arts industry in Sweden.

Suggested actions and the development of tools
This part was based on the results of the investigations at Swedish printing facilities. The project consisted of four separate suggested actions:

- the creation of tools for the printing companies and their customers
- studying the definitions for the different types of separation, and suggesting a new notation
- the development of a ”how-to-do check list” (communication list) for profile creation according to different requirements

Details on the methodology used in the different sub-studies are presented in the included papers.

4 Theoretical considerations

Color reproduction has been studied by many researchers. The elementary principles of color reproduction was described by Yule (Yule, 1967). The publication of *Principles of Color Reproduction* in 1967 was a landmark event in the evolution of photomechanical color reproduction theory and practice. “Here, for the first time, was a complete treatise on the scientific and technical aspects of color reproduction written specifically for the printing industry”, (Yule, 1967). Yule describes color reproduction, color vision, color measurement, color separation etc. The basis of under-color removal (UCR), a type of color separation, is also explained.

Hunt (Hunt, 1970) has defined six different types of color reproduction: spectral, exact, colorimetric, equivalent, corresponding and preferred. Hunt´s explanation of these different ways of looking at color reproduction has a particular relevance to comparisons between original scenes and photographs (Field, 1990). Field described the objectives and strategies for color reproduction and for different image originals. The objectives of a graphic arts color reproduction depend upon the type of original on the requirements of the print buyer, and on the expectations of the end user or consumer of the printed item (Field, 2004).

The research work has undertaken to adapt the IT.8 test chart to a special image category is unique. The ideas and methods concerning IT.8 test charts adapted for printing are the subject of a patent application, where a Swedish patent has been already granted. (Enoksson, 2004). No similar work has been found in this area.

4.1 The need for image classification

Modern image processing involves many ways of reaching the final result, but image processing contains many steps that are being carried out manually without any clear rules. Without clear instructions from customers, the pre-press personnel must nowadays determine subjectively the category of the image, i.e. classify the image. Thus the personnel apply a subjective selection technique to achieve the highest possible quality on their image and on the final product. In order to retain important details in an image, the tone compression needs to be correctly controlled, but when this is carried out manually, the emphasis is on the tone area which one wants to retain to the greatest extent, i.e. to the area to be preferentially viewed in the image. It is here that image classification is extremely important. In the treatment of images with, for example, details in dark areas, it is often necessary to retain more tones in these areas, with a possible loss of detail in bright areas as a consequence.

4.2 The need for a common terminology

A common terminology would make communication easier for all parties involved. It is extremely important to have the same terminology in order to avoid and minimize misunderstandings. Even basic concepts demand correct usage. Consider this example: The printer says that there is too little red in his image, when he really means that there is too little magenta in the print, but to a pre-press person, too little red means that there is too much cyan in the image. An adjustment in the image due to this misunderstanding might have a disastrous effect on the quality of the image. This unfortunate color “language barrier” is a result of there being no single standard for describing color (Green, MacDonald, 2002).

4.3 Automatic image processing

The use of automatic image processing has increased dramatically during the last few years. Automatic image processing saves both time and money, and makes it possible to give customers even better service. Automatic image processing can occur at different levels, with large differences in system economics and complexity. The simplest and cheapest way is to use “Actions” in AdobePhotoshop (see figure 6), or for more experienced users, Applescript* or any of the scripting functions available in Mac OS X*. In other words, it is possible to develop your own methods, at the same time as it is possible to buy more specialized software products for image processing such as Extensis Intellihance Pro, Binuscan IPM Workflow Server and Agfa Intellitune (Haase, 2005).

The most important functions (Haase, 2005) required in automatic image processing are:

- decreasing or enlarging the size of the image, rotating
- changing resolution level, changing the file format
- cropping – according to pre-defined alternatives
- conversion to CMYK. RGB, CIELab or black/white, also CMYK-to-CMYK conversion
- adjustment of shadows and bright areas, adjustment of sharpness
- contrast adjustment, color adjustment and color saturation
- adjustment of color balance and color shift
- removal of deformations, noise and dust

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* main definitions are explaned in the Appendix.
Extensis Intellihance Pro (http://www.macupdate.com/)
Binuscan IPM Workflow Server (http://www.binuscan.com/)
Agfa Intellitune (http://www.agfa.com/)

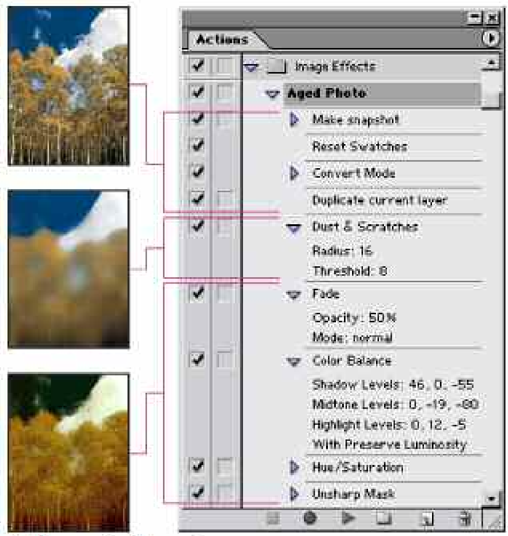


Figure 6 : Function “Actions” in Adobe Photoshop. The example shows the actions applied to an image (Adobe Photoshop CS). An action is a series of commands applied to a single file or a batch of files.

4.4 Images and image categories

The main area of interest in a photograph is the area on which the observer tends to center his attention and this generally contains the main subject or theme elements selected by the photographer. When the photographer prints the photograph he has a choice as to where on the scale of the photograph he will place the main interest area. Depending on aesthetic considerations and the desires of his client, the photographer may use either selected parts of or the entire tone scale. For example, he can place a subject on the highlight end of the tone scale, in which case it would be called “High Key”. Conversely, if he uses the shadow end of the tone scale it is called “Low Key”, and if he uses the entire tone scale it is called “Normal key”. (Jorgensen, 1987)

Images can be divided into different categories depending on their image content, key information and tone distribution. Some of the image categories currently mentioned in literature are: high-key, normal key, low-key (Field, 1990), gray balance and tertiary color images.

In Sweden, there is no standardized terminology for the different image categories, and this means that many different definitions appear. For images dominated by light tones, concepts such as high-key, “snow-image” and “light-image” are used. This can easily cause confusion, as some users think that “snow-images” are the same as winter-images. For dark images, concepts such as low-key, “night-image”, “wet-image” and “heavy-image” are used.

Image classification has been studied in Sweden by several researchers. In the 1980s, Olsson and Germundsson (Olsson, Germundsson, 1990) introduced definitions that are still being used today. These definitions are “snow-image” and “night-image”. Examples of earlier definitions used in Sweden are “light image” and “heavy image” (Beckman, 1991).

The first documented use in offset press in Sweden of the use of different image categories (e.g. “light image” and “heavy image”) to evaluate the print result was in 1977 (Pappersgruppen, 1977). The definition of a light image was that most of the image content was found in the highlights and middle tone range, whereas the heavy image had its main content in the middle tone range and in the shadows. Furthermore, the fact that the ability of people to judge images depends on what the image represents was taken into consideration. For example, it was stated that images of faces and food gave more certain judgments with regard to the print quality than other images. Likewise, it was easier to judge the impact of screen ruling on the print outcome if one had a black and white image in contrast to a color image.

In many cases, the image is explained by help of histogram showing how the 256 possible levels of brightness are distributed in the image, see figure 7. The histogram displays the tonal distribution of the pixels in the image based on their level of brightness, on the *x* axis from dark (0) to light (255). The *y* axis represents the total number of pixels in the image of each level of brightness. If the histogram has the peaks concentrated towards the left-hand side of the graph, this is a “low-key” image. It can also mean an under-exposed image. If the peaks are concentrated towards the right-hand side, the image is “high-key”. (www.shortcourses.com)

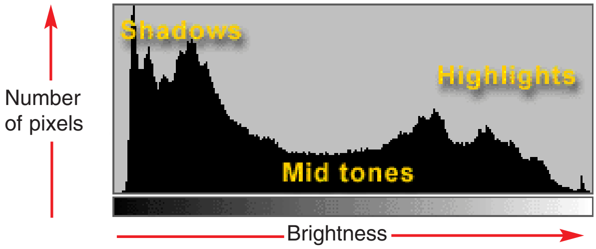
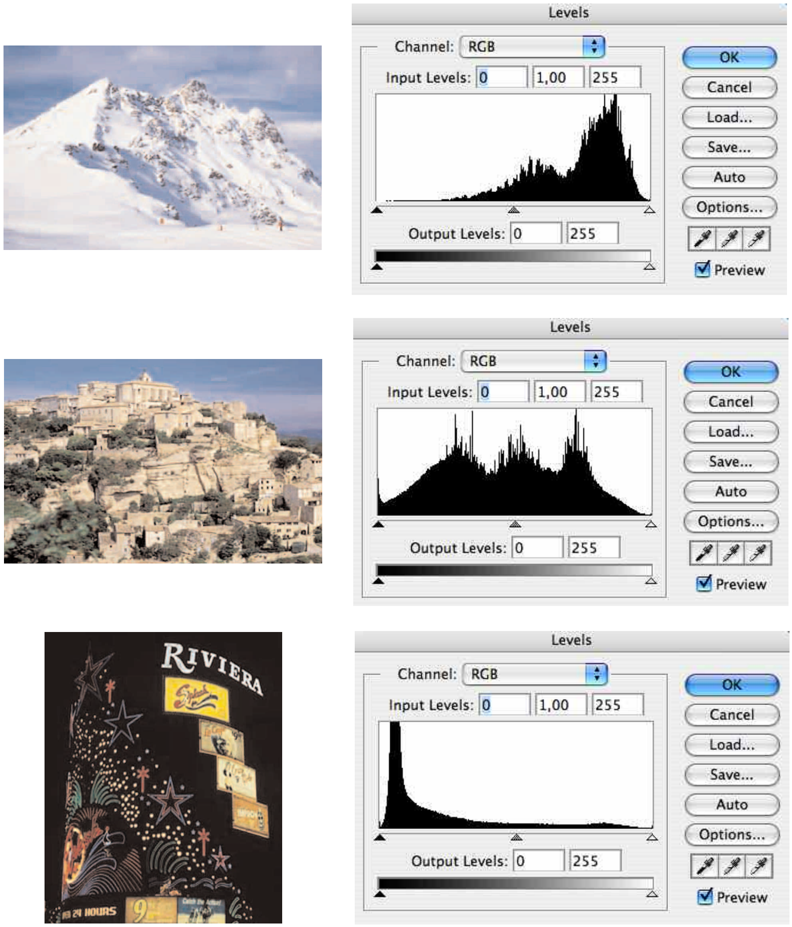


Figure 7: The figure shows how to read a histogram (www.shortcourses.com). Below: Examples of a high-key image, a normal-key image and a low-key image (Royalty free images from Stockpix).



4.4.1 High-key images

High key: A photographic or printed image composed largely of lighter tones in which the main area interest lies in the highlight end of the scale (Field, 2004).

"Snow images" (Olsson, Germundsson, 1990) hold their main information in the high-key areas (lighter tones). The images that are considered to belong to this group are those where the bright areas fill up approximately 60-90% and the dark sections the remaining 10-40% of the total image. In snow-images, the important information to be viewed often lies in bright pastel colors and white shades. The differences in shades are extremely small. The difficulty with this type of image is that the shades approach each other during reproduction and are completely smoothened out in printing. The rougher the surface of a paper, the more the shades will deviate. The image adjustment through dot-gain control, wet-on-wet adjustment and achromatic repro must be somewhat lower than normal for the shade differences in the bright areas to appear more clearly. It is also important to decide where to set the "white point", in order not to burn out details in the brightest section of the image. (Olsson, Germundsson, 1990).

4.4.2 Normal-key images

Normal key: A photographic or printed image in which the main area of interest is in the middle-tone range of the tone scale, or is distributed throughout the entire tone range (Field, 2004).

"Mid-tone images" (Olsson, Germundsson, 1990) have a tone distribution throughout the tone scale with the main information in the mid-tone section. This category is easy to reproduce since it holds information over a wide tone range. However, the mid-tones are subject to a large dot gain which needs to be compensated for.

4.4.3 Low-key images

"Night images" (Olsson , Germundsson, 1990). The main information to be viewed is found in the darker image tones.

Low-key images: A photographic or printed image composed largely of darker tones in which the main area of interest lies in the shadow end of the scale (Field, 2004)

4.4.4 Gray-balance images

"Gray-balance images" (Tidningsutgivarna, 1990). This category has its main information near neutral black. Conventionally, a black and white image would be reproduced in cyan, magenta and yellow (chromatic reproduction). A three color reproduction, without black, is more sensitive to color shifts in a print run because any shift in one of these results in perceptional deviations. A certain amount of black is usually added to stabilize the variations in the print run, which is a degree of achromatic reproduction* or gray component replacement (GCR*).

4.4.5 Tertiary color images

"Dirt images" (Tidningsutgivarna, 1990). A category where the three primaries (CMY) are dominant causing a tertiary color*, usually in the darker tone scale. The tones are closely distributed in the lower end of the gamut*, and this makes it challenging to reproduce the tones correctly in order to avoid a flat reproduction. The difficulties are mainly due to dot-gain*, trapping* and relatively high ink coverage.

4.5 Tonal range and tone compression of images

The human eye can detect a wider tonal range than can be printed. It is not possible to reproduce the complete tonal range of an image in any printing process for many reasons, e. g. limitations in the photographic emulsion, photography using a digital camera, the characteristics of the paper and the limitation of the printing process. The unsurpassed quality of the finest printed color reproduction is due largely to the properties of the substrate and inks used to produce the printed product (Field, 2004). The chosen paper quality affects the quality of the printed image, and the paper characteristics are of great importance for the print result (Johansson, Lundberg, Ryberg, 1998). The composition of the paper as well as the surface treatment also limit the amount of ink that can be used. The amount of ink (and thus the print density), is therefore directly dependent on the paper. The higher the smoothness and the less absorbent the surface of the paper, the higher is the print density that can be achieved. In offset, too high a total ink coverage (TIC*) can cause drying problems and this often results in dirty reproductions/prints (set-of*, rub-of) which in turn may delay the after-treatment and lead to diminished print quality. The TIC must therefore be well suited to the selected paper grade and to the choice of image separation control.

Tonal compression leads to a loss of image information. To be able to take the best possible advantage of the information in the original image, one should, during the scanning of the image, decide which areas of the image should be prioritized. Therefore, it is advisable to evaluate each image prior to scanning, and to decide which areas that are of importance and which are not (Johansson, Lundberg, Ryberg, 1998).

Prior to the scanning of an image, one must consider how large a tone range can be printed on selected paper grades. Problems may arise if all images are treated in a similar manner regardless of what the image looks like and what motifs the image contains. The use of the same type of treatment for different images is often due to pressed time schedules or to a lack of understanding.

Tonal compression necessarily leads to a loss of image information. In most cases, our eyes will not detect this loss of information, as our eyes concentrate upon the "important" areas of the image. To ensure that the reproduction is as similar as possible to the original, we must, already at the scanning, control how the tone compression is to be carried out and which areas of the image are to be given priority. In a generally dark image, i.e. a low-key image, the dark areas should be given priority so as not to lose tonal range in the shadows, and thus decrease the detail rendering. In a high-key image, the bright areas must be given priority. In a normal-key image, the middle tones must be given priority so that these are reproduced as well as possible. In the scanning, low-key images should be therefore scanned with a high gamma-value and high-key images with a low gamma-value.

The electronic scanning of images captured on photographic films is now being used less and less in the printing industry, because most photographers are now using high resolution digital cameras. These cameras capture the images in RGB color space which is the standard in the display of digital images. The users cannot use the gamma value (such as in a scanning process) to correct the tonal range.

4.5.1 Tone reproduction

Tone reproduction is generally the most important aspect of color reproduction. The key requirement in tone reproduction is to find the best compression of the original densities that will consistently result in a high-quality reproduction. The compression could be uniform, emphasize highlights or shadows, or have other characteristics, see figure 8 (*A* is a curve for the high-key image, *B* for the normal-key image and *C* for the low-key image). The optimal tone reproduction curve is probably different for different originals and different people. (Field, 1990).

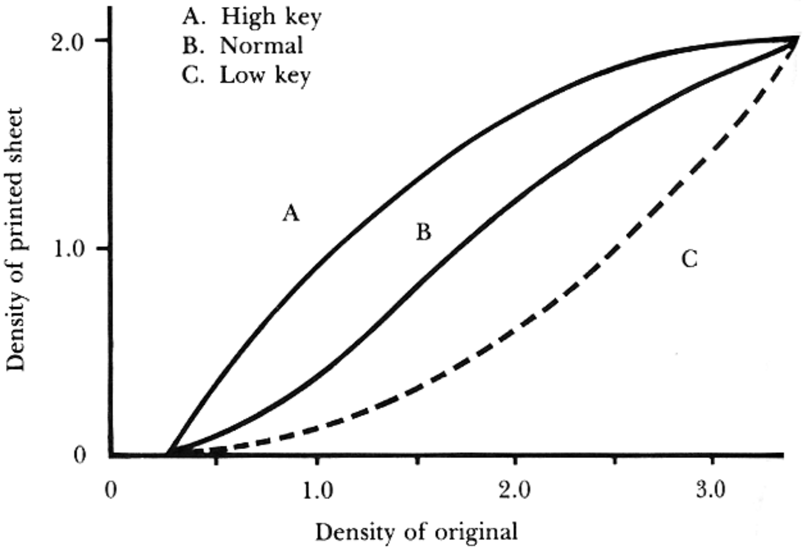


Figure 8: Estimated tone reproduction curves for transparency reproduction, showing interest area emphasis for high-key, normal, and low-key photographs (Field, 1990).

George Jorgensen conducted research on tone reproduction for black and white originals. He found that the preferred curve varied according to whether the photograph was high key or normal (Field, 1990). Jorgensen´s investigations included different observers and different main area of interest. Some of his conclusions (Jorgensen, 1987) are:

- if the main area of interest is in the highlight end of the print´s tone scale, the observer prefers a different tone reproduction curve than when his main interest area is in the middle tones or shadows

- there may be more than a single main area of interest in a photograph and the area selected by the viewer will depend on his interests, taste or bias. The difference in personal viewpoints may preclude a single best or optimum tone reproduction curve for a given photograph

Jorgensen´s research concluded that a tone reproduction curve emphasizing the "area of interest" of the photograph gives the best result (Field, 1990).

4.5.2 Situation today – digital cameras

Today's widespread use of digital cameras means that customers bring their own digital material instead of material prepared by hired professionals. This means varying quality, which may in turn lead to problems later in the process. Most users today struggle to enhance the quality of their images.

The development of digital cameras has increased the number of RGB- images handled and thereby significantly decreased the use of image scanners by the printer. The tone compression is different when digital cameras are used, because the scanning process has disappeared. In scanning, it was necessary to consider the different image categories in order to highlight different areas in an image by adjusting the gamma settings (gamma curve), but digital cameras work in another way. In order to be able to take to account the important details (and thereby the different image categories) present in different areas of an image, it is necessary to know how digital cameras work and to understand which format best holds the information about the image.

Digital camera sensors respond to light quite differently from both the human eye and a film. Most of our human senses display a significant compressive non-linearity – a built-in compression that makes it possible for us to function in a wide range of situations without driving our sensory mechanisms into overload. The sensors in digital cameras lack the compressive nonlinearity typical of human perception; they simply count photons and assign a tonal value in direct proportion to the number of photons detected – i.e. they respond linearly to incoming light. This means that if a camera uses 12 bits to encode the captured image into 4,096 levels, then level 2,048 represents half the number of photons recorded at level 4,096. This is the meaning of a linear gamma – the levels correspond exactly to the number of photons captured. Linear capture has important implications for exposure. If a camera captures information in six stops over the dynamic range, half of the 4,096 levels are included in the brightest stop, half of the remainder (1,024 levels) are included in the next stop, half of the remainder (512 levels) are included in the next stop, and so on. The darkest stop, the extreme shadows, is includes by only 64 levels - see figure 9, so that correct exposure is very important for the quality. Figure 10 shows approximately how we see the same six stops. (Fraser, 2005)

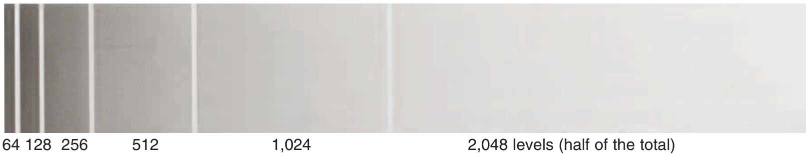


Figure 9: The six stops of dynamic range (= an analog limitation of the sensor).

Figure 10: How we see the six stops from above.

4.5.2.1 The formats

If one uses a digital camera, it is of great importance to know in what format to save the images, in order to control and retain all of the image information. Today, the two main formats are: JPEG* (Joint Photography Expert Groups) and Digital Raw Format (but the TIFF* format also occurs).

A raw digital file is a record of the raw sensor data captured by the camera. Different camera vendors may encode the raw data in different ways, applying different compression strategies, and in some cases they even use encryption, so it is important to realize that digital camera raw data are not a single file format. (Fraser, 2005)

The raw file includes everything that the camera can capture and the user has some control over the interpretation of the image. When the user shoots JPEG, he/she trusts the on-camera settings and the camera´s built-in conversions which discard one-third of the data in a way that does justice to the image (the JPEG format is limited to 8 bits per channel per pixel). (Fraser, 2005)

If you save the RAW data, you can convert it later to a viewable JPEG or TIFF file on a computer. The process is shown in figure 11:

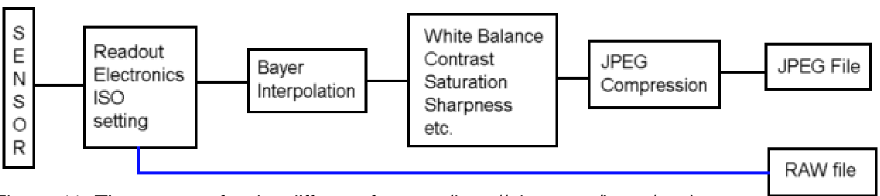


Figure 11: The process for the different formats.(http://photo.net/learn/raw)

JPEG

If the data is stored as a JPEG file, it goes through the Bayer interpolation*, is modified by in-camera set parameters such as white balance, saturation, sharpness, contrast etc, is subject to JPEG compression and then is stored. The advantage of saving data in a JPEG file is that the file size is smaller and the file can be directly read by many programs or even sent directly to a printer. The disadvantage is that there is a quality loss, the amount of loss depending on how much compression is used. The greater the compression, the smaller is the file but the lower is the image quality. Lightly compressed JPEG files can, however, save a significant amount of space and lose very little quality. (http://photo.net/learn/raw)

Raw

The first advantage of saving RAW data is that the user can choose the white balance, contrast, saturation, sharpness etc. he/she wants. The user can change many of the shooting parameters after exposure, but the user cannot change the exposure and he/she cannot change the ISO setting, but he/she can change many other parameters. A second advantage of saving a RAW file is that the user can also convert the data to an 8-bit or 16-bit TIFF file. TIFF files are larger than JPEG files, but they retain the full quality of the image. They can be compressed or uncompressed, but the compression scheme is lossless, meaning that although the file becomes smaller, no information is lost. (http://photo.net/learn/raw)

5 Summary of original work

5.1 Paper I

“Image Classification and Optimized Image Reproduction”

5.1.1 Introduction

ICC-profiles are being used more and more frequently to predict the rendering of colors and thereby ensure a high quality. An ICC-profile is a data file describing the color characteristics of an imaging device (Sharma, 2004). The primary purpose or use of this file is to maintain color consistency in images viewed, displayed or printed on various devices (Wallner, 2000). By using a common format (ICC, International Color Consortium) the for characterization of color units, it is easier to determine the color gamut of a device and thereby optimize a print-out. A device is characterized by printing and measuring target values in a color chart. There are large a number of different color charts on the market, all of which are assumed to be valid for all types of images, no matter whether the relevant image information is located in high- key areas, low-key areas or mid-tones. The result is that too few color tones containing key image information can be analyzed. In the work described in Paper I, new adapted color charts were created based on technical and visual image category analysis. A number of tests have been carried out using extreme images with their key information strictly in the dark or light areas. The results show that the image categorization using the adapted color charts improves the analysis of relevant image information with regard to both image gradation and detail reproduction. The new adapted color charts preserve details in the low-key areas, and give a more distinct image with a better fidelity to the original image. Evaluations have been made using a test panel and the pair-comparison method.

5.1.2 Objective

One purpose of this work was to use the knowledge relating to the categorization of images to improve the quality of color reproduction, and this is achieved by adapting standard color charts. Another purpose was to evaluate different image categories to see whether an advantage can be taken of an output characterization aimed at a specific tone distribution rather than a static characterization aimed of any kind of tone distribution.

5.1.3 Method

The previous work of Enoksson regarding borders between image categories was used. Test charts commonly used for output characterization were studied to evaluate how the tone steps are distributed for output characterization, and a new set of color values was used to create an image-adapted test chart, different from the gamma and gradation values normally used. These category-adapted test charts were printed under controlled conditions. Spectral measurements were made on the new test charts, and new output profiles were calculated and applied in the RGB-to-CMYK conversion for the specific image category aimed for. A validation print was made with the new separation values applied to the specific image category aimed for. The results were evaluated by the subjective pair-comparison method, where 50 persons with a graphic arts background judged the result. An objective evaluation was made by instrument measurements of lightness values.

5.1.4 Background to the creation of an image category border - classification using L*-values

In order to establish more distinct borders between the different image categories, tests were carried out with L*-values (L= lightness). The project started with a selection of digital color images, where a selection of 30 images were chosen to fit these characteristics, also including “middle tone images”, see figure 12.

High-key image | Normal-key image | Low-key image

Figure 12 : Examples of a high-key image, a normal-key image and a low-key image.

The distribution of the L*-value in the three types of images indicates of the borders that may exist between these images, see figure 13.

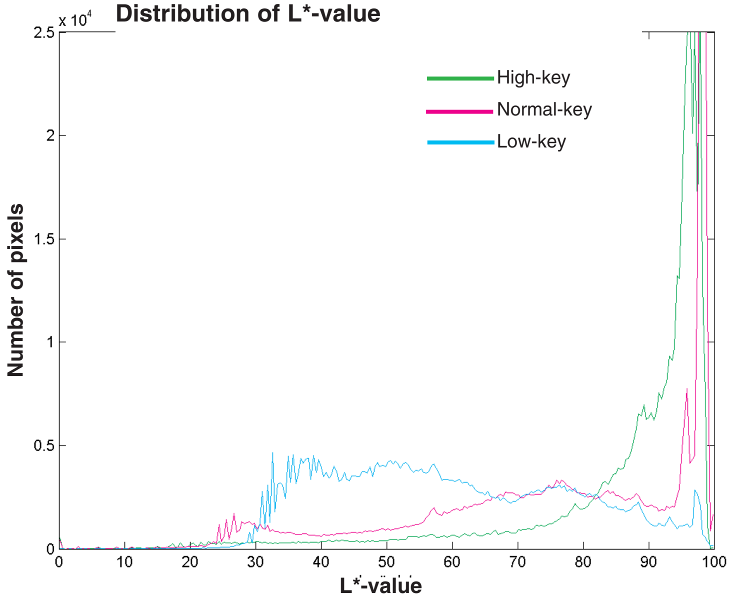


Figure 13: Distribution of L*-value for high-key, normal-key and low-key images. The peak for high L-values in the normal-key image is caused by the white background. The graph is created in Matlab (Enoksson, 2001).

The images were processed in Adobe Photoshop, where the color information was discarded in order to analyze only the L*-values. The images as well as their histograms were studied and analyzed using the Matlab-software, see figure 14.

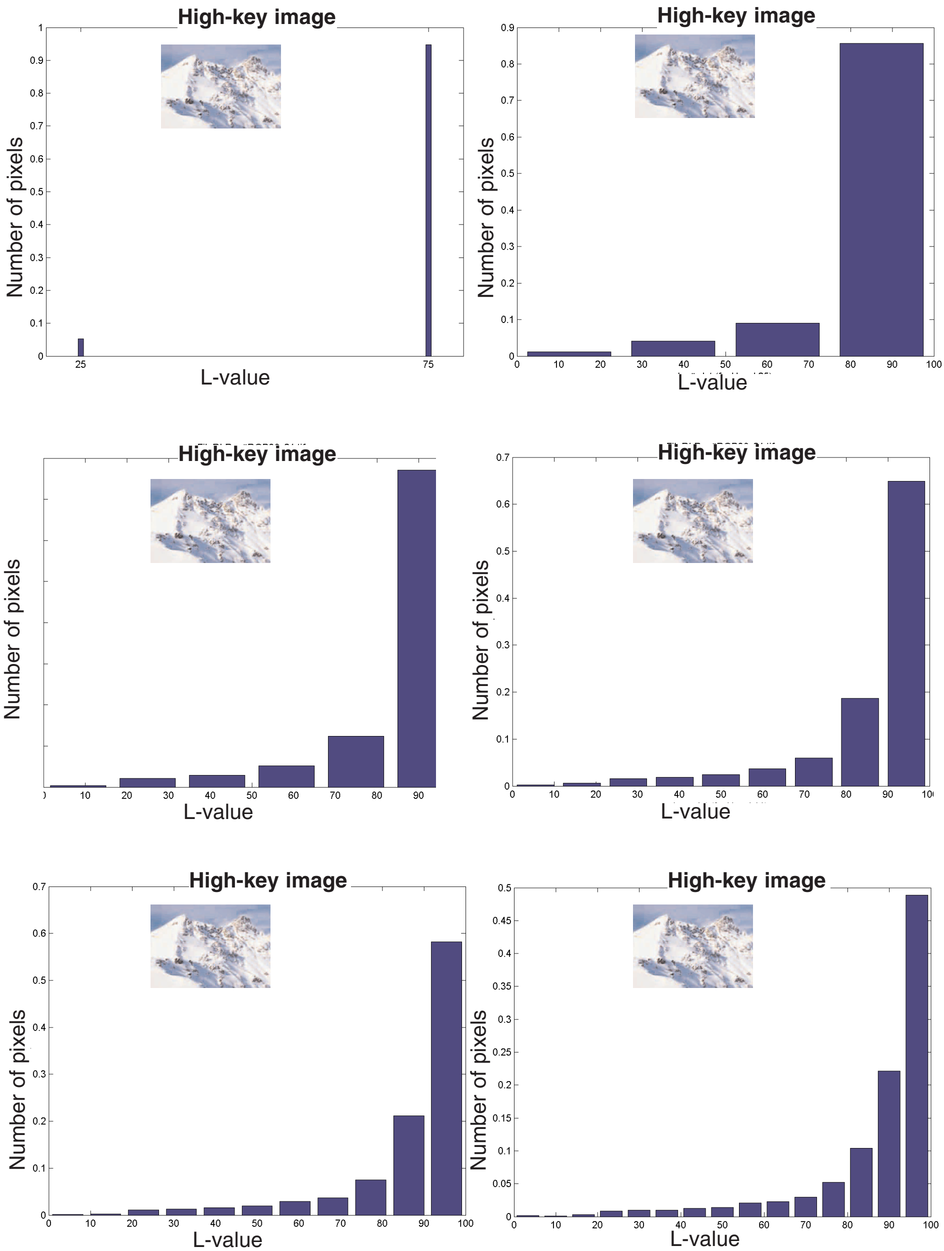


Figure 14: The steps made in the Matlab analysis. Number of pixels in different steps of L* scale in high-key image.The steps made it possible to find the borders between the images.

The demarcations of the L*-values for the different image types were used to create an image-adapted color chart.

Each image category was printed in an offset press, Heidelberg Speedmaster 74-6, on a coated (130g/m^2) and an uncoated (130g/m^2) paper. The prints were processed and separated using Adobe Photoshop, where the color information in the images was compressed against adjacent colors, turning them into an IT.8-target (24x18 patches) for easier measurement, see figure 15.

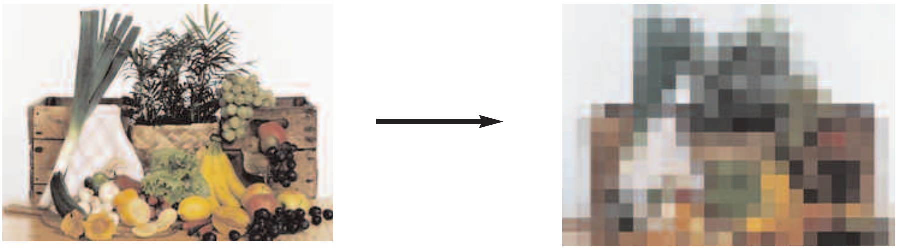


Figure 15: Adapting of the image (normal-key) to - an IT.8 target - 24x18 patches.

The patches of the images were measured using a spectrophotometer and the CIELab L*-value was computed. The measured values were used to compare for the three image categories the L*-values in the original data and the L*-values on the coated and uncoated papers, see figure 16. The figure clearly shows that the scatter of the L*-values in the images was compressed by the different paper grades. On an uncoated paper, the dark areas are clearly lighter, which means that there is a poorer detail rendering in the printing.

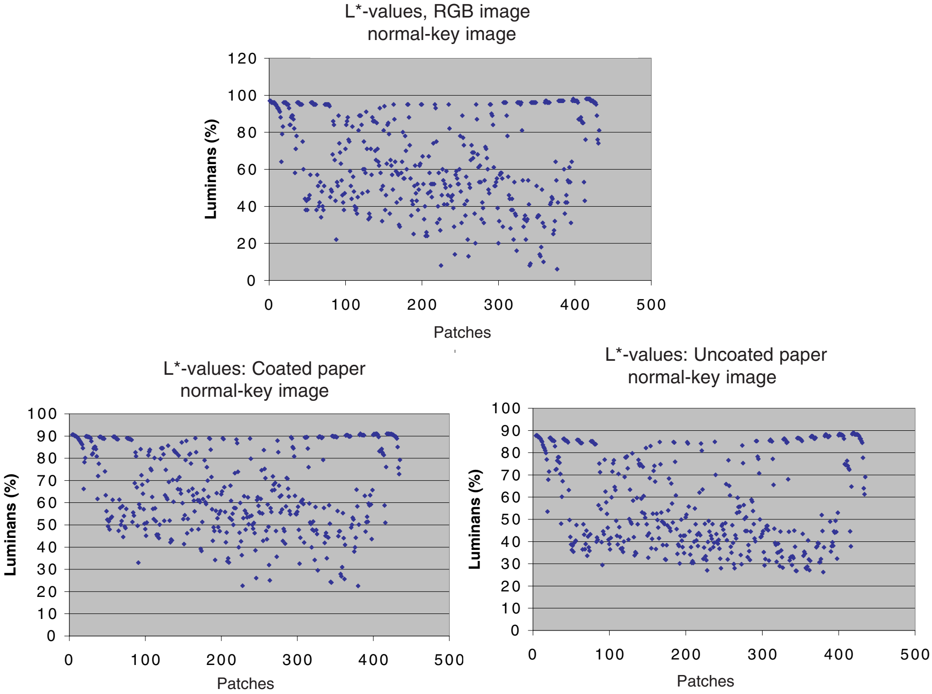


Figure 16: Distribution of L*-values for a normal-key image and for prints on coated and uncoated paper.

5.1.5 Results - Image classification by using L-values

The studies of the three image categories (high-key, low-key, normal-key) revealed that the borders in the L*-scale for high-key images were 100-60, for normal-key images 60-40 and for low-key images 40-0, see figure 17.

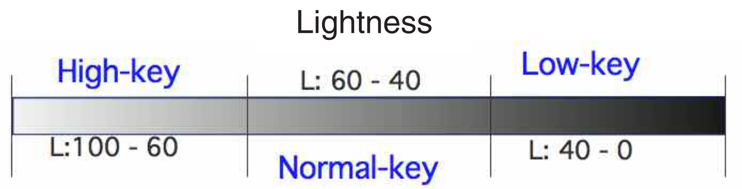


Figure 17: The borders in the L*-scale (Lightness) for high-key, normal-key and low-key images (Paper I).

5.1.6 The image adapting of the test chart

Are there other solutions that will make it easier to give priority to interesting areas than is usually done by tonal compression or optimal separation (GCR - Gray component Replacement, UCR - Under Color Removal)? The beginning and the end of the production chain, both offer an adaptation to the production and method of giving priority to certain image categories and areas of an image.

Each part of the graphic industry has high demands on color reproduction and the demands of the print buyers and end users for quality are steadily increasing. Color communication between scanners, computers and output devices has improved, thanks to ICC-profiles. There are several companies developing software for profiles on the market. Each of these products is designed to help the user achieve improved color fidelity, each one looks and works differently and may produce different results (Adams II, 2000). Each software has its own color test chart. Test charts differ from each other in the number of color patches , the values of the patches and the color distribution. The test charts have one thing in common - they are intended to work for any kind of images with no focus on any particular image category.

The hypothesis in this work has been that it is possible to adapt the test chart to the image category and thus give priority to sections of the tonal range. Tests of this hypothesis have revealed that there are two ways to adapt the test chart:

a) to create a new adapted test chart
b) to adapt the standard test chart

a) Creation of a new adapted test chart

The borders suggested in figure 17 were used to create a new image-adapted test chart, as shown in figure 18. For some patches, the Neugebauer equations have been used.

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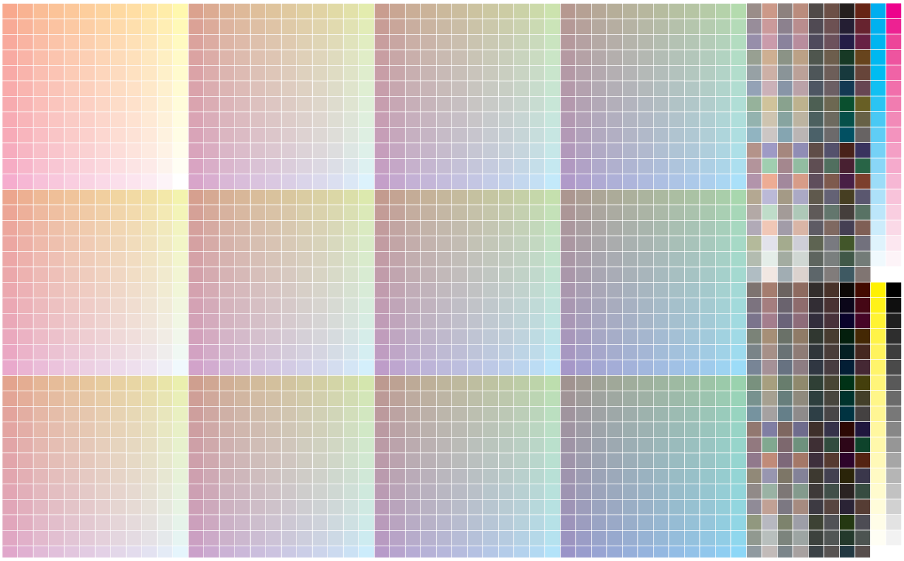

Figure 18: An example of the new image-adapted test chart.

The construction of the test charts available at the market was studied and the values of these test charts were measured and compared (Paper I). The new test charts were created based on the suggested borders between image tone values, see figure 17. The distribution of the values generates a slope that can be compared to a gamma curve for the different image types (Paper I).

b) Adapting of the standard test chart

Another way of adapting the test charts is to adapt the standard test chart. The same knowledge about the gradation from the earlier study was used. The the standard test chart 6.02 was adapted in software AdobePhotoshop (Paper I).

5.1.7 Results - adapting the IT8. test chart for printing

A new printing was carried out (Heidelberg Speedmaster 74-6) using these test charts and subjective and objective evaluation of the prints were carried out:

• the subjective evaluation used 50 people from the graphic industry and from the Graphic Institute. A paired comparison (Bristow, Johansson, 1983) was made of the prints. People involved in this evaluation preferred the prints which based on separations with the adapted test charts, see figure 19.

• for the objective evaluation, gray scales were created in Adobe Photoshop and separated with the same profiles as for the images. The gray scale which was based on a separation with the adapted test chart showed more detail in the dark tones.

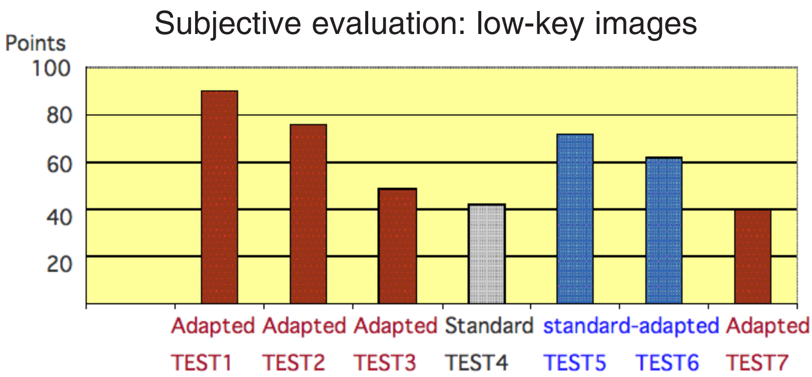

Figure 19: The result of the subjective evaluation. The y-axis shows the points for the test charts (Paper I)

The low-key prints which based on a separation with the image-adapted test chart showed more detail in the dark areas, as can be seen in figure 20.

Figure 20: A comparison between low-key images after printing. The image to the left was separated with the standard test chart and the image to the right with the image-adapted test chart.

5.1.8 Conclusion

The results suggest that an adjustment only to low-key images is sufficient, as even normal-key prints then show a better fidelity to the original image. High-key images show no difference between the different IT.8 test charts, see figure 21. Classifying images is a difficult task, as it is the customer who should ultimately decide which areas of an image are most important. The general reasoning that high-key images have the greatest concentration of information in the bright areas, normal-key images in the middle-tone areas and low-key images in the dark areas of the tone scale is quite reasonable. An "exact" mathematical definition can be produced, but it loses its value directly for the graphic industry as it does not help in the actual image processing. An analysis of the pixel numbers in an image in the L*-scale generates suggested borders that can be applied in further studies. These borders make it possible to adapt of the IT.8 test chart for printing with pleasant results. IT.8 test charts for scanners also permit a certain adaptation for its one´s production or for specific colors.

The ideas and methods concerning the adaptation of IT.8 test charts is the subject of a application, where a Swedish patent has already been granted. (Enoksson, 2004). No similar work was found by the patent company.

5.1.9 Comments

The test form for printing the IT.8 test charts can be complemented with a compensation of the test chart, e.g. the method published by Nordström (Nordström, 2003), in order to achieve the optimal ink coverage in the particular printing press.

Tests with the adapted test charts have also been performed with an ink-jet printer, HP Designjet 5500. (Åman, Lind, 2004). The results of these tests also suggest that the adapt test chart leads to a higher detail level in the dark areas of a low-key image.

There are also other parameters which can impact on print quality. The quality of a color print is not established simply by the hue, saturation, and lightness of individual areas; image definition (resolution and sharpness) factors also play a significant role (Field, 2001).

The low-key image showed more details in dark areas.

Normal-key image showed a better agreement with the originals.

High-key image - no distinctions among them could be observed.

Figure 21: The low-key image showed more details in dark areas. Normal-key image showed a better agreement with the originals. High-key image - no distinctions among them could be observed.

5.2 Paper II

"The characterization of input devices by luminance and chrominance"

5.2.1 Introduction

Both the beginning and the end of the production chain offer possibilities for an adaptation for one´s own production and to give priority to certain image categories and areas in an image. The beginning of the process is the creation of the scanner profile with the special test chart for the scanner.

5.2.2 Objective

The aim of this study was to evaluate how different IT8-test charts for scanners correlate with each other, with the ISO-standard and with different RGB color working spaces used in imaging applications. Each scanner chart holds a specific gamut of colors for a scanner to capture. If a flatbed scanner can precisely scan each color patch colorimetrically correctly, then a scanner profile (ICC) would not be necessary. However, each color which is incorrectly scanned according to its colorimetric value will need a color correction when being converted from the source profile (scanner) to the destination profile (RGB color working space).

5.2.3 Method

The scanner profiles capability can be evaluated by using a test image with a few known color values with high chroma. The result can be evaluated according to known color values. Three IT8.7/2 test targets were used in the test. Besides the established IT8-targets from the major color chart vendors a new IT8-target was created for the tests. The four test charts are named A, B, C and D in the study. Reference color values such as lightness and chroma coordinates were read from the test targets. A spectrophotometer was used for the readings.

The following seven stages describes the tests performed:

1) Comparison of the different input profiles (A, B, C), with raw scanning (gamma 1) and gamma 2
2) Comparison of the different profile connection spaces
3) Comparison of the different profile to the ISO-standard ISO 12641-1997
4) Comparison of Delta E and Delta E-94 differences between the ISO-standard and the different scanner targets

5) Lab comparison of the RGB and CMY color values from the digital test image towards the physically measured RGB and CMY values from the IT8-targets (A, B,C)
6) New test chart creation
7) Modification of test charts output saturation and how this affects the gamut

5.2.4 Adapting the IT8.target for scanners

There are several vendors producing IT8-targets for scanner characterization. The targets follow a certain pattern,. based on ISO standardization values in LCH (ISO 12641-1997).

The scanner target consists of a total of 264 colors, as shown in figure 22. The target design is a uniform mapping and is defined in detail in the ANSI standard IT8.7/2 for reflection material (ISO 12641-1997)

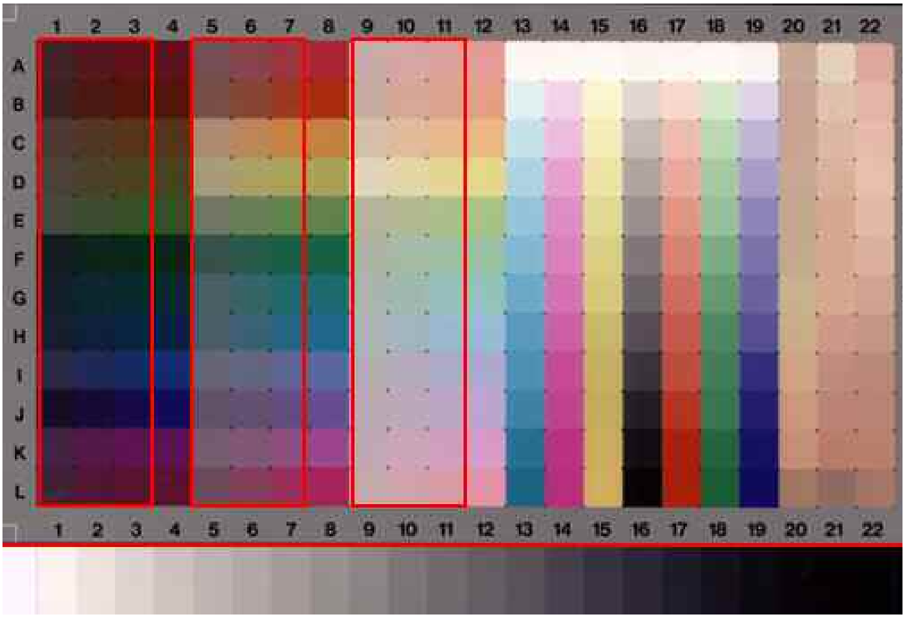

Figure 22: The scanner target consists of a total of 264 colors. The red frames show the standardized values.

Twelve separate hue angles are defined at three separate lightness levels. For each specific hue angle and luminance level, there are four different chroma values. The highest chroma value is defined as the maximum chroma which can be output on a given medium with no change in the hue angle and lightness level. A further 84 patches provide additional tone scales which are not defined by any ISO-standard. Seven tone scales are defined for the colors cyan, magenta, yellow, red, green and blue (no ISO standard defined). Each tone scale is built-up in twelve steps starting from the lowest chroma value and keeping the hue angle stable. Each vendor has defined an optimal tone scale for their own specific output media.

The last three columns in the test chart are vendor-specific. Here the vendor manufacturing a target was allowed to add any feature they deemed worthwhile. Each vendor has chosen to use this area differently. Kodak has chosen the image of a model and several skin tones patches; Agfa and Fuji have both chosen to have patches of special colors in this area (McDowell, 2002).

A scanner profiling program makes it possible to characterize the color reproduction of a scanner and thus :

- to optimize color on input, and
- to synchronize the appearance of multiple scanners, so that a large production job can be divided among several scanners with no noticeable difference in color reproduction characteristics (Adams II, Lind, 2001)

5.2.5 Result - adaptation of the scanner test chart

It is possible to produce a custom-made IT8 target and achieve a result similar to the obtained with the standard test charts on the market. The advantage of producing your own test chart is that it is possible to achieve a better match to the originals being scanned. In addition, customized color patches can be added for specific color values, as shown in figure 23.

Figure 23: The customized IT.8 target for scanners made by Enoksson and Aviander .

5.2.6 Conclusions

The color charts differ in color gamut when using the same settings. To more accurately capture an image with a certain color gamut, the scanner ought to be characterized with a similar or slightly larger color gamut so the image gamut falls within the ICC profiles color space. Reference readings of the IT8 test charts need to be measured at fixed intervals in order to receive a more correct color gamut. In order to keep the color gamut of an image stable throughout the reproduction process, it is crucial to have a similar input profile size as the original color space and the profile connection space. This will keep the colors unaffected throughout the conversion stages.

The three major test charts producers (A, B, C) plus the new IT8-target differentiate from each other which will affect the color conversions from the scanner profiles to the profile connection space.

5.3 Paper III

"Image Reproduction Practices"

5.3.1 Introduction

Original images handled by the prepress departments are usually digital images in the RGB-mode (Red, Green, Blue). However, in order to print an image it must be converted into the printable base colors, CMYK (Cyan, Magenta, Yellow, Black). This color conversion is today done by ICC-profiles. The profiles contain information about separation, black start, black width, total ink coverage. GCR (Gray Component Replacement) and UCR (Under Color Removal) are the two main color separation techniques used to control the amounts of black, cyan, magenta and yellow needed to produce the different tones. Since black ink can 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 also 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 a printing process must normally be reduced in order to avoid printing problems such as slurring and quality problems such as lack of image detail.

5.3.2 Objectives

The purpose of this study was to investigate the level of knowledge concerning image separation and the use of ICC-profiles in the graphic arts industry in Sweden.

5.3.3 Method

The investigation has involved two separate studies over two different periods of time.

The first study was performed in 2000 when ICC-profiles were used by only a minority of Swedish printers. The color separation, at that time, was 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, with an even geographical spread over the nation. The printers and prepress houses were also chosen on the basis of the size of the company, but only companies with two or more employees 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 be able to assess the general level of competence.

The second study was performed in 2003. Eighty sheet-fed offset printers and 34 newspaper printers, evenly geographically spread over 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 either through 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 per cent 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

5.3.4 Results and Conclusion

The studies indicated a serious problem in the graphic arts industry. The problem was related to both insufficient knowledge of color management and lack of communication. With regard to knowledge, there was a lack of competence and a shortage of literature and instructions which could help printers to better understand the technology. The communication problem was due to a lack of a common language, due mainly to the different backgrounds and experiences of the people involved. A knowledge of other people's field of expertise is necessary to establish better communication between, for example, pre-press and printing personnel. The studies also show that there is a need for further education in the graphic arts industry.
:

The first study showed that:

- only a minority (20%) of the printers and prepress houses had a good knowledge of how their image conversion was performed
- more than 50 per cent of the printers asked for dedicated technical training in their field
- there is a need for instructions and guidelines written in an understandable way
- the instructions must be written to be understandable by non-experts
- there is often poor internal communication within companies, especially between the press operators and the prepress staff working with imaging and the consultants

- there was a common hope that an ICC implementation would solve the major color reproduction difficulties

The second study showed that a majority (70%) of the commercial printers nationwide in Sweden are using ICC profiles for color reproduction, particularly (83%) in the newspaper industry. The majority of the participants in the survey felt that there was a lack of communication or a non-existing communication in all process directions. There is normally no dedicated time for quality meetings.
The newspapers have a better know-how than commercial printers concerning color management. Few companies set a strategy for their color management implementation and they therefore may not use the consultant in the right way. Terminology confusion is common in the graphic arts business. The study shows that many pre-press staff members use the terms incorrectly or mix them up. The survey indicates that external consultants play an important role in the creation of ICC-profiles.

5.3.5 Comments

This lack of knowledge is not a feature only of Sweden. Other studies (Marin, 2004) have revealed that other countries have similar problems. Developing ICC profiles is not necessarily an easy process. Based on the data collected (Marin, 2004), the following were the top five problems the respondents experienced in implementing color management software:

Top five Problems with Profiling
1) Device calibration
2) Misunderstood profiling set-up options
3) Lack of understand of the profiling process
4) Inappropriate test target
5) Inappropriate profiling software
(Marin, 2004)

A company must achieve quality by understanding and improving systems and by preventing problems (Apfelberg H, Apfelberg M, 1999).

It was shown that there was a great need to further educate the personnel in printing. Training in elementary color theory and explaining the commonly used types of software are of great importance.

5.4 Paper IV

"A Digital Test Form for ICC-profiles"

5.4.1 Introduction

Studies (see Paper III) performed during the years 2000 and 2003 revealed that the graphic arts field has a knowledge problem. The problem concerns both an insufficient knowledge of color management and a lack of communication. The people within the graphic arts field complain about the shortage of literature and instructions which could help printers to better understand the technology.

An increasing number of graphic arts companies are using ICC-based color reproduction. The companies either create their own printer profiles, or hire consultants to create the profile. A survey described in Paper III, showed that 70 per cent of the Swedish sheet-fed offset printers need the assistance of a consultant in the ICC-profile creation process. The choice of software tool plus the software-specific separation settings are also made by consultants. Printers/prepress houses have difficulties in adjusting specific parameter settings in the profile, due to insufficient color management skills. The survey proved that there is a need for pedagogic tools in order for the user to better understand their own process. All graphic terms and techniques set high demands on the users at printers and prepress departments.

5.4.2 Objective

The purpose of this study was to create a digital test form using the most common color imaging software on the market - Adobe Photoshop – in order to promote the practical understanding of profiles and their use.

5.4.3 Method

The project focus was to find a suitable mix of images and test areas in order to illustrate the differences in color spaces, gamut colors, color renderings and separations in a simple and pedagogic way. A number of applications have been tested for the creation of the test form, as Adobe Illustrator 10,0 and Adobe Photoshop 7.0 were the final choice. Eight graphic consultants, three printers and their customers have been acting as a test panel in order to evaluate the test form created.

The test form is intended for use in Adobe Photoshop, since this application is most widely used for color imaging in Sweden.

5.4.4 Result

The created test form can provide information to the user about many settings in the profile. The test form helps to show the differences between the settings already in the RGB color mode and to avoid misunderstandings after printing. The layout of the test form facilitates the practical understanding by showing the result of a color conversion from RGB to CMYK using a profile.

The digital test form gives information about:

- ICC profiles in MacOS and Windows
- Different color gamuts
- RGB Gray balance
- Rendering intents
- Gamut warning
- Separation
- CMYK gray balance
- Chroma shift
- Gamut mapping
- Skin tones
- Total Ink Coverage

The images are pedagogically developed in order to facilitate the understanding and the ability to analyze changes in the settings of a profile, figures 24 and 25.

5.4.5 Conclusion

The digital test forms were tested by consults in the graphic arts industry and by a number of printing companies in Sweden. The test form has achieved its goal to increase the understanding of profiles and their use.

5.4.6 Comments

Printing personnel are often short of time, and the maintenance of production goes before all testing. The personnel are, in other words, fully concentrated on handling the production demands, leaving little time for personal initiative. To read manuals and thereby learn more about a certain software has been shown to be a poor alternative, as manuals are often written in a difficult way, and often in a foreign language. Exercises that are based on a “step-by-step” approach often help the user to solve a lesser problem, but without granting the user any deeper knowledge. What the graphic arts industry needs is a tool that helps the users to help themselves. By using such a tool, the user can test the different settings and applications included in the software, and later apply this newly gained knowledge to his own productions, his own color proofing system, printing machine, etc. Furthermore, graphical definitions should preferably be exemplified by pictures, facilitating the understanding of definitions, explanations and any differences.

Figure 24: The digital test form for the evaluation of ICC-profiles (Enoksson, 2004).

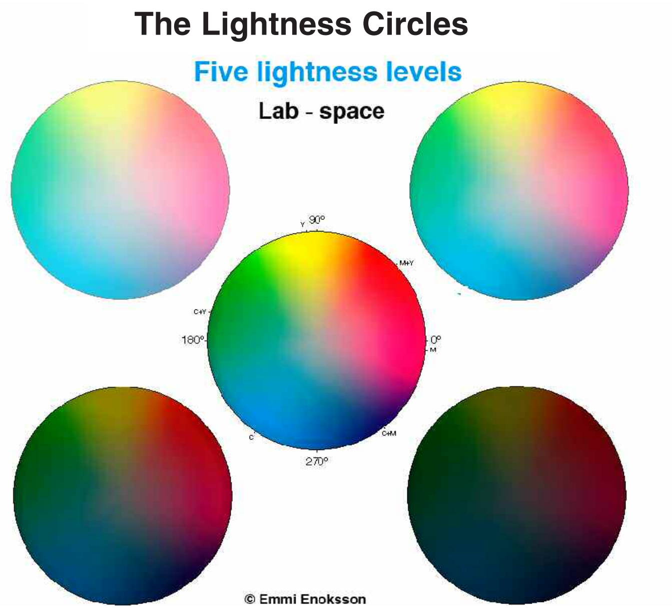

Figure 25: The lightness circles in five levels for evaluation. To better understand how the settings affect the result, the user can see the changes in two directions - the vertical direction (the matrix on the digital test form, see figure 24) and the horizontal direction (the lightness circles on the digital test form).

5.5 Paper V

"Demand specifications for controlled color reproduction"

5.5.1 Introduction

An increasing number of printers are using ICC-based color reproduction, to improve repeatability and predictability in the color reproduction process. Many printers use external color consultants for their color management integration. The information they give to the printers concerning the specific parameters used in the profile creation varies.

In order to be able to have a constructive discussion between all participants in the color reproduction chain, it is vital that each reproduction step be fully understood, optimized and controlled. General reproduction guidelines can be a useful aid in communication to optimize each step in the color reproduction process.

5.5.2 Objective

The purpose of this paper was to define specifications to simplify and improve color communication not only between consultants and printers but also internally between the prepress and pressroom departments within the company.

5.5.3 Method

The communication list is based on visits to printing companies and a survey. Thirty lithographic offset printers in Sweden were contacted during 2004 by e-mail, telephone or personal visits to clarify their internal technical specifications relating to color management. Visits were made to 15 of these companies. The survey questions were prepared to enable the demand for specifications between printing companies and external consultants, as well as internally between the prepress and press departments, to be analysed This survey was complemented with visits to another 20 printing companies and two paper mills. The interviews in this part of the survey were semi-structured. Five color consultants have been interviewed after the surveys to verify the result and in order to obtain a general impression of their points of view. The questions in these interviews were also semi-structured.

5.5.4 Result

A list describing the specifications one should understand when building an ICC-workflow for print reproduction has been constructed. An understanding of these specifications will facilitate internal communication within a printing company, and also between printing companies and external consultants creating ICC-systems.

The survey showed that none of the printing companies had a well-prepared list of specifications for the construction of ICC-profiles other than ”functioning profiles” and that people relied on each others´ competence. The survey also showed a great need for a ”how-to-do check list” for profile creation, which would be helpful to facilitate communication internally and externally.

The discussions with consultants in the graphic arts industry tended to bring up “process thinking” more and more often. According to the consultants, we must learn to see the graphic printing business as a process industry. Each process (i.e. prepress, press, postpress) needs to be linked to others. In order to link the processes, we must understand the specifications for each process, what to input and what to output and who is responsible for the process. All processes used must be defined and a process representative must be defined and given responsibility to act. During training sessions for printing personnel, prepress personnel should also attend (and vice versa) so that the knowledge of each others´ disciplines increases, and communication is made easier. An improved communication will give a better process understanding and thereby a better production quality. Thus communication is the key word, both orally and written. We have to learn to communicate in a way which is comprehensible non-experts. This will strengthen a company´s production process. Better communication gives better quality – both internally with the company and to the customers. Education of these involved is needed to achieve better communication.

5.5.4.1. The color communication list presented in five parts:

1) General demands/specifications

This part of the list contains objectives, implementation and specification. Before a profile-based production can be considered, comprehensive objectives need to be set. The purpose of the process change must be explained to the personnel directly involved in the production process. General information about profile implementation needs to be given. To avoid common misunderstandings and improve internal communication, written process instructions should be followed. Each process should be defined and described, with regard to responsibility and demands.

2) Test form specifications
This part describes responsibility distribution according to the creation and content of the test form.

3) RIP specifications
This part of the communication list describes initial demands – linearization and setting of the RIP.

4) Output profile specifications
This part describes responsibility distribution according to settings in the profile.

5) Printing specifications
This part describes initials demands, general facts and standard demands.

Is not a complicated task to produce profiles if the specifications for the separate processes are well defined. For each process, there must be at least one person in charge. There must be pre-established control measurements of the process with given tolerances and instructions regarding the frequency of measurements. Control data must be saved over a period of time in order to simplify fault-finding in the event of non-confirmative results. Each step in a color management set-up must be documented so that a later profiling update can be established with the same set-up. What specifications are crucial for the internal communication within a printing company? If the printing company uses a color consultant for the print profile creation, for which process steps is the consultant responsible and which steps are the printers' responsibility? By confronting these issues beforehand, many mistakes can be avoided, simply by using a more direct communication.

The communication list deals with specification demands that are of importance in the development of profiles and different responsibility distributions in the development of these profiles. Two scenarios are described: the first situation is when the printing company creates its own profiles without the involvement of an external consult, and the second scenario describes the situation when the printing company needs external help to create the profiles.

5.5.5 Conclusion - the communication list

Introducing a profile-based process flow involves planned work with clearly detailed goals. It means a thoroughly worked out plan with a clear goal from the start. All processes used must be defined and a process representative must be appointed and given with responsibility. Effective communication between the printing and prepress departments is the goal. During training sessions for printing personnel, prepress personnel should also attend (and vice versa) to increase the understanding of each other´s disciplines and facilitate communication. It is important to point out that the printer´s role has changed. Apart from having the printer´s skills, a more active part must be taken in the prepress work must be taken. An improved communication will give a better process understanding and thereby a better production quality. When constructing a profile, the process owners involved must participate. One person should lead the process, preferably from the printing press area, and there must be a documented information interchange between all involved parties.

“It is important to know that color management is more than just making or using ICC-profiles. Color management requires calibration, process control, collecting good measurement data, understanding application and drive settings, and above all, bringing all these together into a coherent workflow” (Fraser, 2003).

Based on a survey (Marin, 2004), these points should be kept in mind to help achieve success when implementing color management:

- process controls should be implemented in your organization before trying to color manage the workflow
- the color management process requires training
- know that color management is a process
- give it time

External customer demands for quality are growing continuously. Therefore, a continuous improvement in the quality of goods and services produced by the company is vital. Improving continuously is an important element in a successful quality strategy. The costs for poor quality in the Swedish industry are often estimated to be 10-30% of the sales (Bergman, Klefsjö, 2003). As an example of the consequences - see figure 26.

This happens if we accept that 99% correct is sufficient:

- Nine words are incorrectly spelled on each page of your newspaper.
- Almost four times per year you will not get your newspaper.
- You should be without electricity, water or heating about 15 minutes each day.
- At least 8 500 prescriptions should be incorrectly prepared each year.
- About 23 700 transfers should each day be made to the wrong account.
- Drinking water in the waterpipe system should unusable about 1 hour per month.

Figure 26: En example of the consequences in “Kvalitetsbristkostnader” (Hedman, Lindvall, 1993)

5.6 Paper VI

"Compensation by Black - a New separation?"

5.6.1 Introduction

There are basically two types of separation: UCR and GCR .These separations can reduce or remove a gray component made up of yellow, magenta and cyan inks and replace it with a suitable amount of black ink. These separations are still a major cause of confusion, as very few users actually know what these separations mean and how the settings affect the final result.

5.6.2 Objective

The aim of this paper was to examine the differences between UCR (Under Color Removal) and GCR (Gray Component Replacement).

5.6.3 Method

This study explains the differences between GCR (Gray Component Replacement) and UCR (Under Color Removal) by testing these separation functions in three applications: Adobe Photoshop CS (an image editing application), Gretag Macbeth's Profile Maker 5.0 (profile maker), and Heidelberg's Print Open 4.0.5 (profile maker). The literature relating to the different types of separation was reviewed. An Internet search was also made to check what a prepress employee would find if he or she was to search for a definition of one of these types of separation.

5.6.4 Background - UCR and GCR

Already in an article in the RIT T&E Center Bulletin (September-October 1984, vol.12, no 6) written by Franz Sigg and Patty Cost, it is possible to read: "The term UCR would therefore no longer be used, because its function would be fully covered by GCR". Twenty-two years have passed since this article was written by Franz Sigg and Patty Cost, and nothing has happened since then. The situation has not been made easier for the users, and no attempt has been made to increase their understanding. Why not?

The original meaning of UCR was lost about 25 years ago when the third generation of electronic scanners targeted the lithographic printing industry. The first theoretical principles of UCR were developed by Yule, and his theories were first applied to conventional separations, and later to the first electronic scanner, the Time-Life/PDI scanner in the early 1950s, see figure 27. The limitation of conventional masking methods in applying UCR to neutral tones only later became the standard opinion about UCR. In a later paper, Yule expressed his regrets that the initial scope of UCR had been perceived to be limited to neutral tones. He then went on to say that this had become the "standard opinion" in the industry, and he therefore introduced the concept of Extended UCR.

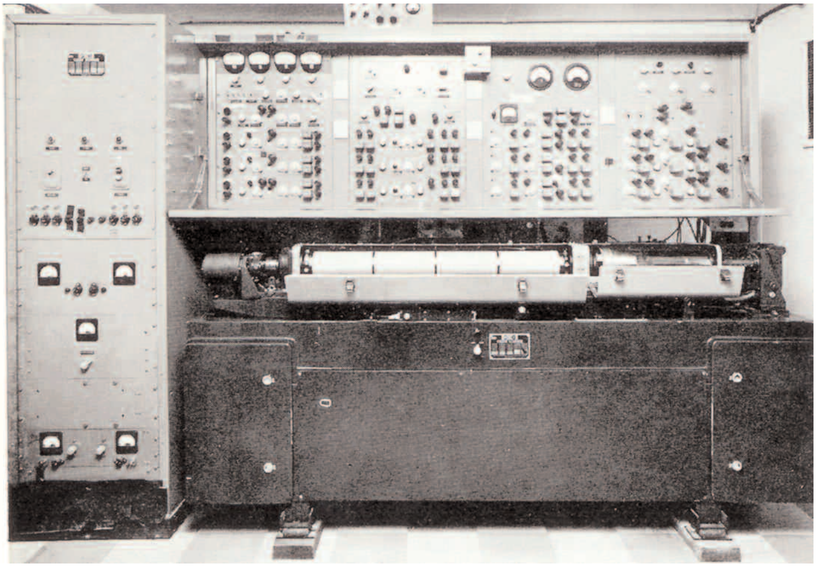

Figure 27: The figure (Carlsson,1967) shows the Time-Life PDI scanner from the 1950s. The first application of UCR in electronic scanning was used (Yule 1940). Size = XXXL and very heavy. Same size exposure – transparency to separated con-tone negatives. Capacity < 3-4 times the conventional methods .This scanner was used for Time and Life publications printed in wet-in-wet (trapping problems).

Later, Extended UCR became known as GCR and inventive marketing from the leading electronic scanner manufacturers in the early 1980s has contributed to the confusion. "New" functionality was marketed in the beginning of the 1980s, and new acronyms were coined: PCR, CCR, ICR.

PCR (Polychromatic Color Reduction)	Crosfield
CCR (Complimentary Color Reduction)	Dr Hell
ICR (Integrated Color Removal)	Dai Nippon Screen

5.6.5 Results

The investigation of both recent literature (1989 - 2004) and manuals from frequently used software shows that two different types of separation, GCR and UCR are described. The difference is that UCR works only in the neutral dark areas and that GCR seems work over the entire tone range (where the three CMY-colors are present).

The tests in the three applications (Adobe Photoshop CS, Profile Maker 5.0 and Print Open 4.0.5) generated similar results for UCR and for the lowest level of GCR. It is difficult to draw a border between these two separation types . UCR is really a "light type"of GCR or "GCR level 1"

5.6.6 Conclusion

The study has led to two alternative proposals:

1) *Discard the term UCR and use only GCR,* as it really only concerns gray component replacement. This would make it easier for people in the business to focus on the process itself instead of trying to understand the difference between the two types of separations, a difference which cannot be seen visually.

2) *Discard both terms and introduce a new term: CB* (Compensation by Black). The software should make it possible to choose how much black will be used and where it will replace a combination of the CMY process colors. In addition, a single term would make the user more aware of the problems of separation and of how separation will affect the print result.

The suggestions imply an extensive review of accepted terms and abbreviations within the graphic arts industry in order to achieve a uniform scientific meaning and definition. Thus, it is strongly recommended that the term, CB (Compensation by Black) should be implemented.

5.7 Paper VII

"Using Gray-Balance Control in Press Calibration for Robust ICC Color Management in Sheet-Fed Offset"

5.7.1 Introduction

When ICC profiles were first used, there was a tendency to create profiles for many different combinations of printing presses and papers. It has even been stated that a new ICC profile needs to be made for each new paper delivery. Naturally, this would be overwhelmingly time-consuming and expensive.

Today, it is more common to reduce the number of ICC profiles, and most parties benefit from fewer profiles. How many profiles are needed, and which way of working is then required? The idea behind this paper was that the fewer the number of ICC profiles for sheet-fed offset, the better. To make this possible, printing presses must be calibrated. Calibration was accomplished by combining target density levels and gray-balance control.

Cold-set printers often use gray-balance fields for the adjustment and control of ink quantity during print runs. This method helps the printer to significantly reduce unwanted color cast in the printed product. A common technique to control the amount of ink in sheet-fed offset is to decide upon target tone-value increase (TVI/dot gain) or density levels, with the intention to print the best subjective quality, even though the same quality cannot always be attained in every print run. Today, a predictable and equal quality is generally desirable, and calibration and standardization are therefore more in focus. Since there is no standardized way to calibrate a sheet-fed offset press, the possibility of producing an equal print quality in different print runs and printing presses is limited.

Gray-balance control is one way to calibrate a printing presses. The press will then always be set to print one standardized combination of CMY halftones in the same way. Hopefully, this will create a similarity between print runs, presses and to some extent paper grades, which provide the foundation for robust ICC profiles.

5.7.2 Objective

The objective of this study was to find a way of calibrating a sheet-fed offset press, so that the color reproduction on different papers will be similar enough to permit the use of fewer of ICC profiles.

5.7.3 Method

The use of gray-balance control in sheet-fed offset was explored and the stability of ICC profiles was assessed in gray-balance-controlled print runs. The inking levels in the press was set to print given CMY combinations neutral on five wood-free coated papers (ISO12467-2). If the press is always set to print this standardized CMY combinations so that the result looks the same, it should be possible to use the same ICC profile in all the print runs.

ICC profiles were created for each of the five papers and they were then used for all of the papers, in gray-balance-controlled print runs. To compare the different combinations of ICC profiles and papers, CIE LAB images and test charts were converted to CMYK, printed and then measured or evaluated visually. The deviation in ΔE-units was used as a measure of the stability.

5.7.4 Result

It was found that it was possible to print without a color cast, and still keep print contrast, density, dot gain and CIELAB values for the secondary colors at an acceptable level. Prints on different coated papers were compared, to investigate the similarities between these samples, when using this method and ICC profiles. The study showed that a single ICC profile can give similar print quality on different papers.

5.7.5 Conclusions

It was evident that gray-balance control can be utilized in sheet-fed offset. The printable color gamuts and the neutrality in the three-color gray were sufficiently similar between papers and print runs to enable good gray-balance control to be achieved. However, in sheet-fed offset gray-balance control should be used in combination with target density levels; the “gray-balanced” targets have to be controlled and, if necessary, adjusted in each print run.

The ICC-profiles created from the gray-balanced print run were found to be quite robust. Combining the results from the objective and subjective evaluations, the following three conclusions could be drawn:

- the printed results were similar when the gloss or dull (silk) ICC-profile was used on the classic matte, dull (silk) and gloss papers

- the printed results were similar when the classic matte ICC-profile was used on the classic matte, matte and dull (silk) papers

- if an average $\Delta E \leq 3$ and the worst $\Delta E \leq 5$ are considered to be good enough, one ICC-profile for coated (fine) paper ought to be sufficient, preferably created for a glossy paper

6 Conclusions and discussion

The aim of this work has been to establish criteria for an easier understanding and thereby optimal printing of different image categories.

6.1 The first objective

The first objective of the work was to investigate methods for categorizing and classifying images in order to make it easier to understand image processing in relation to the results of the image-adapted process chain.

6.1.1 Problems regarding image classification

The category to which a certain image belongs depends on how one looks at an image. As an example, consider an image showing a dark-haired girl in a white dress with advanced embroidery. The classification of this image is affected by the thought process, as well as by the customer’s wishes/priorities:

• If the image is to be used in advertising for instance, and one wants to emphasize the different features and qualities of different hair dyes, then the girl´s hair, the quality of the hair and the sheen of the hair are of primary importance. This means that the bright areas, which are of secondary character in this case, will be “flat” in printing, as adjustments are made with respect to the darker areas in the image. See figure 28.

•If the image is supposed to appear in a magazine showing clothes, then the girl´s dress is of primary importance. The bright areas need extensive processing in order to fully reveal the details in the pattern of the dress. The dark areas, the girl´s hair, will lose detail due to this prioritizing. See figure 28.

• If the picture is to appear in a make-up magazine, then the girl´s face, a normal-key area, is considered to be of primary importance. Both the bright areas, highlights, and the dark areas, the shadows, will lose their detail in the image. See figure 28.

Problems may arise if the customer claims that all details in an image are of equal importance. The printer (under such circumstances) may suggest the use of five, six or more colors, and perhaps an overprint varnish to provide the tone reproduction that the customer desires. If the printer is restricted to using four colors and no overprint varnish, tonal compression is inevitable in most cases. In this case, the key to good tone reproduction is a non-linear compression that favors the area of interest in the photograph (Field, 2004).

Figure 28: The girl to the left shows her hair, the girl in the middle shows her dress and the girl to the right shows the make-up. (Images are simulated).

Another problem that the pre-press worker may have to face arises when he/she has received no instruction at all from the customer. Will the subjective judgment of the pre-press workers determine which areas of the image are the most important?, see figure 29. The answer to this question is “yes”. The pre-press worker must in this case decide to which area he/she should give priority and treat the image on the basis of these decisions.

Figure 29: The image to the left has priority in showing the jewellery and the watch, the image to the right shows more detail in the underlying cloth.

6.1.2 The image adaptation of the test charts

In order to render an image in the most optimal way, one can adjust the printing settings by deciding which area of the image contains the most important information. This information can be adjusted in various ways – for instance by choosing the gamma curve during the scanning, or by adjusting an IT.8 test chart for scanners or for print. These adjustments to the IT.8 test charts generated good print results. The adaptation of an IT.8 test target for scanners made it possible to adapt the production. The advantage of producing a tailor-made test chart is that it makes it possible to achieve a better match to the originals being scanned. Customized color patches can be added for specific color values and this improves the color rendering. This thesis work suggests that it is possible to produce a custom-made IT8 target and achieve a result at least similar to or even better than with the standard test charts on the market.

Adapting the end of the process chain makes it possible to give priority to certain areas in an image. Adjusting the low-key images also generates a better color rendering in normal- and high-key images. The actual adaptation works like a built-in gamma. An adjustment only to low-key images is sufficient, as even normal-key images then show a better fidelity to the original images. High-key images did not show any difference between the different IT.8 test charts, and no distinctions among them could be observed in the prints. Offset process variations are probably the main reason for this.

6.1.2.1 Image adaptation of the test chart for printing

The low-key image separated by the image-adapted test chart showed more detail in the dark areas than a low-key image separated by the standard test chart, in the prints on a coated paper. The coated paper has a smooth surface to which it is easier to transfer the dots. On coated paper, the printed halftone dot has an even edge, whereas an uncoated paper gives an uneven dot shape. Uncoated paper gives more dot gain* than coated paper. Dot gain is not in itself a problem, but if uncontrolled it results in a deterioration of quality. The surface and the structure of the paper are sources of an (apparent) dot gain. An uncoated paper gives a greater light scattering than a coated, glossy paper and thus a greater optical dot gain. This optical part of the total dot gain is considerable, and the only way to reduce it is to change to a better quality of paper (Hansson, Aviander, 2006).

Due to dot gain it is difficult to achieve the same high quality on an uncoated paper as on a coated paper. The detail in the dark areas of the image has a tendency to disappear. The image adaptation of the test chart printed on uncoated paper may give even more detail in the dark areas.

6.2 The second objective

The second objective was to investigate the level of understanding of image separation, the use of ICC-profiles and color management in printing houses in Sweden and on the basis of these results, to try to identify the problems and suggest solutions to solve them.

6.2.1 The studies

Two studies were performed (during the years 2000-2004) at printing companies in Sweden to assess the knowledge level, and the level of understanding of image separation and the use of ICC-profiles in the graphic arts industry. The studies indicate a serious problem in the graphic arts industry, involving both a insufficient understanding of color management and a lack of communication. There is a lack of competence and a shortage of literature and instructions which could help printers to better understand the technology, and there is no common technical language. There is clearly a need for further detailed education in the graphic arts industry.

The following actions are suggested:

a) the further education of personnel
b) the development of material that explains graphical definitions in a simple and pedagogic way
c) a clearer responsibility distribution in the organization
d) a simplification of the graphical definitions

Today, printers play a more central role in the process where the demands for understanding are increasing. The printers must not only be the masters of the printing process, they also have to take a more active role in the prepress process. Color separation settings performed in profiling applications often affect the printers'work without their knowledge. Printers must be offered greater possibilities to change the settings in software that create the ICC-profiles used for printing. Without this ability to change settings, no understanding is achieved, and communication between the different groups is weakened.

Not only printers need further education, other groups in the graphic production chain, for example pre-press personnel need further education as well. Software used at printing companies is under constant development; new versions are becoming available more and more rapidly. As a consequence, the personnel need more time study the new functions.

There is a need for instructions and guidelines written in an understandable way. Reading manuals can be quite a difficult task, so these instructions must be written in for non-experts so that everyone can fully understand the instructions and guidelines.

6.2.2 The communication list

Communication between different departments of a printing facility must be improved. The pre-press department and printers must co-operate in the development of ICC-profiles. If external help is used, extensive documentation should be provided. A communication list has been prepared, listing the important demands for specifications one should understand when building an ICC-workflow for print reproduction. These demands for specifications will facilitate not only the internal communication within a printing company, but also the interaction between printing companies and external consultants building ICC-systems.

6.3 The third objective

The third objective was to make color management understandable for the users and thereby optimize printing. For this purpose, digital test forms have been developed. These test forms, together with descriptive material, will facilitate the understanding of color management issues. Definitions within the field of color separations have been examined, and changes have been suggested.

There is no short cut to knowledge. One way to gain knowledge is to test how different settings and functions work. Practical use tends to grant a greater understanding then mere reading. For this purpose, a digital test form has been created. The goal of the test form is to facilitate the practical understanding of ICC profiles and their use. The test form will help to point out the differences between the settings and different functions already in the RGB color mode and thereby avoid misunderstandings and disappointments after printing. The layout of the test form facilitates a practical understanding by showing the result of a color conversion from RGB to CMYK using a profile.

A new tool/kit for evaluation of ICC-profiles had been created. The goal of this educational kit is to facilitate and exemplify the practical understanding of profiles and their use for the users.

6.3.1 New easier terminology

Terms are often described differently in the literature and on the internet. Examples of these are the techniques used to separate images - UCR (Under Color Removal) and GCR (Gray Component Replacement). These different and non-defined terms are confusing for the all whole graphic arts industry. Tests made the currently available software (Adobe Photoshop - image processing, ProfileMaker - profile creation, PrintOpen - profile creation) have shown that there is no greater difference between UCR and GCR. UCR has been shown to be a “GCR light”, as was suggested already in 1984 (Sigg, Cost, 1984): “The term UCR would therefore no longer be used, because its function would be fully covered by GCR”. The present work emphasizes that this 22 year old suggestion is still valid. It is important to make it easier for the users to understand the technique in a more simple way. Therefore, a new term has been proposed - CB (Compensation by Black). This new single term would make the user more aware of the problems of separation and of how separation affects the print result.

6.3.2 The educational tools

The working material in the educational kit consists of five parts:

1) Basic color theory

To be able to work with ICC-profiles, a basic knowledge of color theory is needed. In this kit you can find the basic theory you need before starting to work with the profiles.

2) The digital test form for ICC-profiles - testing of ICC-profiles in Adobe Photoshop

This educational kit provides the user with simple descriptions of different graphical definitions and settings that the user can also test by himself. The definitions are described in a simple manner, often with screen dumps from the software. In order to fully understand how different settings affect the final result, the user must test them.

3) Excel file

The user can also print the actual test form, type the measured values and interpret them on the attached Excel file, where he/she can analyse results in the form of a diagram.

4) Different settings in profile making softwares PrintOpen and ProfileMaker

In the kit, the user will also find ISO-profiles (ECI-Offset 2004) and profiles made in PrintOpen and ProfilMaker. These profiles have been created using different settings (e. g. different kinds of separation, black width, black start, gamut mapping etc). These profiles are created using the settings that the user can test himself using the included test forms.

5) Books and websites for additional reading

The user will find some useful links and books for additional reading.

The user can convert the digital test form to the CMYK color mode and analyze the changes in the test form. For a better understanding of the settings, the user can duplicate the digital test form and convert it in different ways. The user can compare the results and see the changes in a pedagogic way because of the composition of the test form. To see, for example, how the black ink works in an image (the different settings for UCR - Under Color Removal, GCR - Gray Component Replacement, black start and black width), the user can study the black channel (in Adobe Photoshop) after the conversion. To better understand how the settings affect the result, the user can see the changes in two directions - the vertical direction (the matrix on the digital test form) and the horizontal direction (the lightness circles on the digital test form, see figure 25). The different settings for color conversions are described in the educational kit (Enoksson, 2005), see figure.30.

Figure 30: The educational kit for evaluation of ICC-profiles, (Enoksson, 2005)

7 Concluding remarks

The research work has been applied practically, and has resulted in a patent concerning image adaptation, a survey of the level of understanding of color management, communication list concerning ICC profiles, an educational kit and a proposal for a new separation terminology .

The results of the image adaptation suggest that an adjustment only to low-key images is sufficient, as even normal-key images then show a better similarity to the original image. The low-key image shows more detail in dark areas.

The surveys revealed the immediate need for education, guidelines and tools.

The communication list will facilitate communication not only internally within a printing company but also between printing companies and external consultants creating ICC-systems.

The goal of the educational kit is to facilitate a practical understanding of profiles and their use.

This is very important to make it easier for the users to understand terminology. A proposal has been suggested based on separation. The new term “Compensation by black”, CB, has been suggested. A single term should make it easier for the users to understand and use the different settings which impact the image reproduction.

8 The author´s contribution to the papers

Paper I - Enoksson Emmi
"Image Classification and Optimized Image Reproduction"
The entire study was carried out by me.

Paper II - Enoksson Emmi, Aviander Per
"The characterization of input devices by luminance and chrominance"
I have carried out the research in the paper together with Per Aviander. I came up with the initial idea, planned the all trials and did almost all measurements. I was responsible for the writing of the paper, Per Aviander was responsible for the writing in English. I was responsible for the presentation of the paper.

Paper III - Enoksson Emmi
"Image Reproduction Practices"
The entire study was carried out by me.

Paper IV - Enoksson Emmi
"Digital Test Form for ICC-profiles"
The entire study was carried out by me.

Paper V - Enoksson Emmi, Aviander Per
"Demand specifications for controlled color reproduction"
I have carried out the research in the paper together with Per Aviander. We have mutually visited several printing houses and did many interviews with the personnel. I have gathered and compiled all the answers and suggested "The communication list". I have written this report and Per Aviander has translated it in to English. I was responsible for the presentation of the paper.

Paper VI - Enoksson Emmi, Bjurstedt Anders
"Compensation by black - a new separation?"
I have carried out the research in the paper together with Anders Bjurstedt. I developed the initial idea, planned all the trials and did all the measurements and analyzed the results. Anders Bjurstedt wrote the history part in the paper. I was responsible for the presentation of the paper.

Paper VII - Nordstedt Sofia, Kolseth Petter, Enoksson Emmi
“Using Gray-Balance Control in Press Calibration for Robust ICC Color Management in Sheet-Fed Offset”
I have carried out the research in the paper together with Sofia Nordstedt and Petter Kolseth. Sofia Nordstedt has been responsible for the research and she has done all the trials and measurements. I have supported the initial idea, planned the trials and aided in making the conclusions together with Sofia Nordstedt and Petter Kolseth.

Appendix - Central concepts and terminology

AppleScript

AppleScript is an English-like language used to write script files that automate the actions of the computer and the applications that run on it. It is much more than a macro-language that simply repeats your recorded actions, AppleScript can make decisions based on user interaction or by parsing and analyzing data, documents or events. (www.apple.com)

Additive color system - see also Color mixing systems

The additive color process begins with black, or the absence of light and therefore no color, and it involves transmitted light before it is reflected by a substrate. Adding and mixing the three primary wavelengths of light (red, green, and blue) in different combinations produces a full spectrum of colors. Adding all the primary colors in relatively equal amounts produces "white" light, see figure 31. Computer monitors, television screens, projection TV, and stage lighting are based on additive color mixing (Adams, Weisberg, 1998)

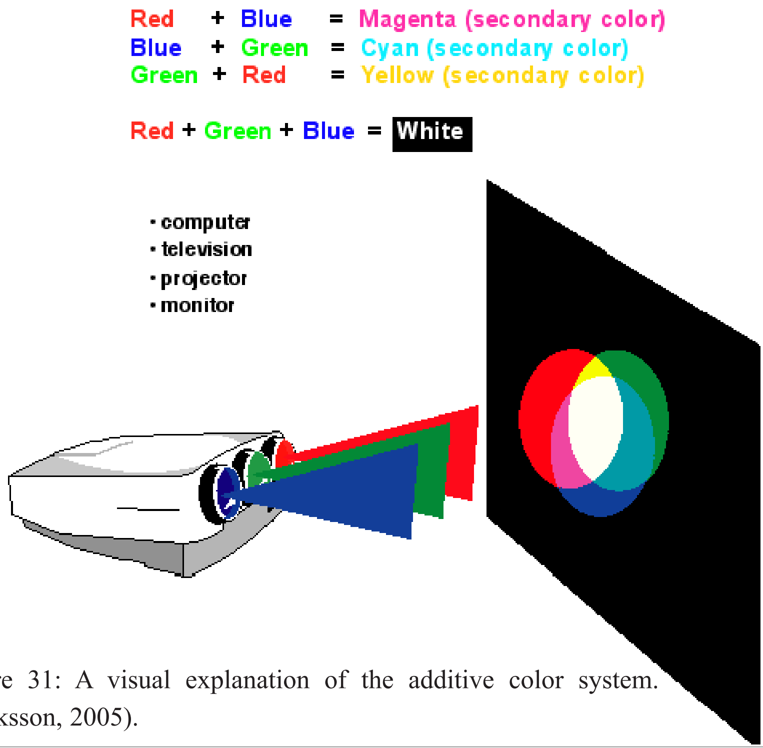

Figure 31: A visual explanation of the additive color system. (Enoksson, 2005).

Achromatic reproduction

Conventional reproduction is chromatic, i.e. the colours are made up, in particular, of the three colours C, M and Y. Black is used only for creating contrast in pictures. In achromatic reproduction, a part of the colours is replaced with black. This gives a clearer print and less set-off. (http://www.ddpff.dk)

Bayer interpolation

The digital sensor in the majority of digital cameras is what is known as a Bayer pattern sensor. This relates to the arrangement of red-, green- and blue-sensitive areas. Figure 32 shows a typical sensor. Each pixel in the sensor responds to either red, green or blue light and there are two green- sensitive pixels for each red and blue pixel. There are more green-sensitives pixels because the eye is more sensitive to green, so the green channel is the most important. The sensor measures the intensity of light falling on it. (http://photo.net/learn/raw)

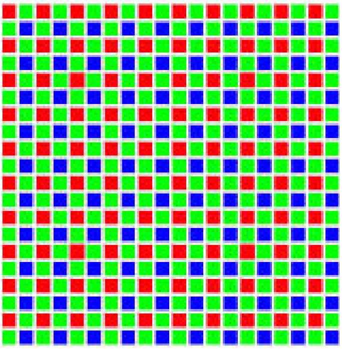

Figure 32: A typical digital sensor, known as a Bayer pattern sensor.

Calibration

The adjustment of a color production device (scanner, monitor, printer) to match an established performance specification or standard (Field, 2004).

CIE

Commission Internationale de l´E´clairage (the International Commission on Illumination), an international standards-setting organization for colorimetry and related optical radiation measurements (Field, 2004).

CIELAB color space

The 1976 CIE color space transformation with the dimensions L*, a*, and b*, in which equal distances in the space represent approximately equal color differences.

CIELAB, or CIE L*, a*, b*, is a three-dimensional plot calculated from CIE XYZ tristimulus values, in which L* is lightness, a* is the red-green axis, and b* is the yellow-blue axis. The CIELAB color space has been widely adopted for surface color measurement applications (e.g. printed products). (Field 2004).

CIE XYZ
A set of three values describing the color of an object, based on a standard illuminant and observer, provides the “raw” color measurement data used to make ICC profiles.

Color cast
A color´s tint deviation, such as yellowish green, pinkish blue, reddish gray, etc. Usually refers to a distortion of hue (Field 2004).

Color gamut
The range of colors that can be formed by all possible combinations of the colorants used in a color reproduction system (Field 2004).

Example on working color gamut: sRGB, AdobeRGB, Color Match RGB, see figure 33 and 34. Different RGB color profiles differ from each other (CMYK color profiles do so also) by size, gradation (or gamma), saturation and to some degree hues for red, green, blue, cyan, magenta and yellow. These differences affect the color conversion, even if the conversion (separation) is to the same CMYK color profile.

Adobe RGB
Adobe RGB has a larger color space than Color Match, see figure 33. This color space is today the most frequently used RGB-standard in the production of print media. Adobe RGB is a relatively large color space, and only a few monitors can display all of its colors. Gamma 2,2, D65. (Johansson, Lundberg, Ryberg, 2006)

ECI RGB
ECI RGB is a relatively new standard developed by European Colour initiative (ECI) and has approximately the same color space as Adobe RGB (1998) (Johansson, Lundberg, Ryberg, 2006)

sRGB

The sRGB standard, developed by Hewlett-Packard and Microsoft, is based on the HDTV standard (High Definition TV = TV standard with high quality). Hewlett-Packard and Microsoft use sRGB as a standard for office software as well as for web browsers. sRGB is based on the color space that a normal PC monitor can display. However, this is also the limiting factor for the sRGB. Its color space is smaller than to other RGB-color spaces normally used in graphical productions, and it is not suited for images that are to be printed, as large areas of the CMYK-color space are outside this color space. Gamma ca 2,2, D65. (Johansson, Lundberg, Ryberg, 2006)

ColorMatch

ColorMatch is based on the RGB color space that can be displayed by a Radius Press View monitor. Radius monitors were formerly commonly used in professional graphical productions, but they have a relatively small RGB color space, and are not optimal for graphical purposes. Gamma 1,8, D50. (Johansson, Lundberg, Ryberg, 2006)

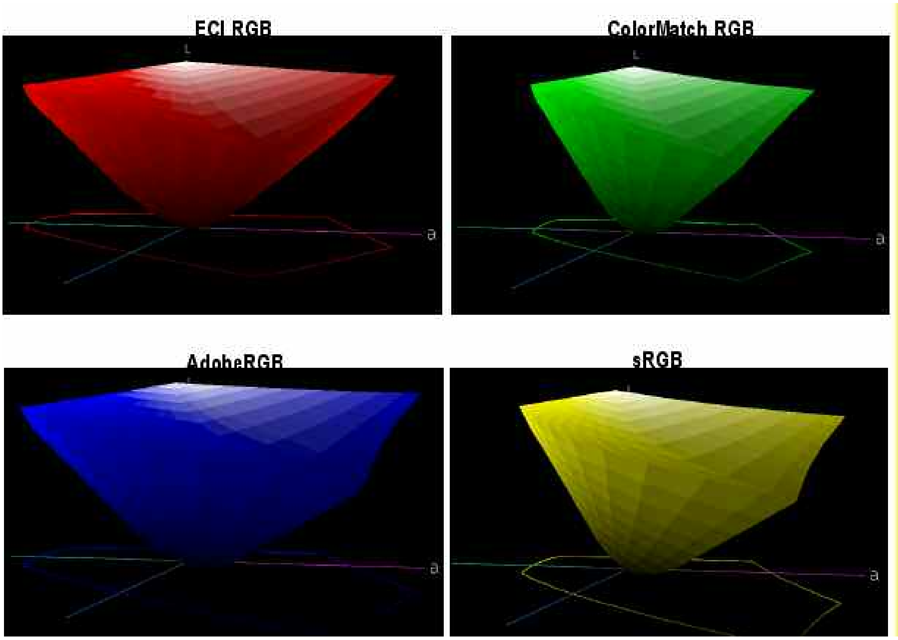

Figure 33: The sizes of the different working color gamuts.(Enoksson, 2005).

Name	Gamma	Reference white	Red Primary			Green Primary			Blue Primary		
			x	y	Y	x	y	Y	x	y	Y
Adobe RGB (1998)	2.2	D65	0.6400	0.3300	0.297361	0.2100	0.7100	0.627355	0.1500	0.0600	0.075285
ColorMatch RGB	1.8	D50	0.6300	0.3400	0.274884	0.2950	0.6050	0.658132	0.1500	0.0750	0.066985
ECI RGB	1.8	D50	0.6700	0.3300	0.320250	0.2100	0.7100	0.602071	0.1400	0.0800	0.077679
sRGB	≈ 2.2	D65	0.6400	0.3300	0.212656	0.3000	0.6000	0.715158	0.1500	0.0600	0.072186

Figure 34: Description of the different working color gamuts.(http://www.brucelindbloom.com)

Color mixing systems: RGB and CMYK see also Additive systems
The graphic industry uses two main color mixing systems: the additive system RGB (the primaries colors are red, green, and blue) and the subtractive system CMY (the primaries colors are Cyan, Magenta, and Yellow). Both systems are device-dependent systems. This means that the reproduced color is depending on the device, the condition of the device - the age, the structure, the pigment, the substrate etc.

Color separation
The process of making intermediate images from the color original to record the red-, green-, and blue-light reflectances. These images are used to prepare the cyan, magenta and yellow printing records, see figure 35. A black separation is also made. (Field, 2004).

Conversion
Translating a colour image from the colour space of one device to that of another. More rigorously known as *colour conversion*. (Adams, Weisberg, 2000).

CMYK - see Color mixing systems

Dot gain
Net percent increase in halftone dot size (or tone value) through the tone scale or at a specified percentage (e.g., 50%). A dot gain of 20%, then, signifies that a 50% tint reproduces as 70% apparent dot area (Adams, Weisberg, 2000).

Density
The ability of a material to absorb light. Expressed as the logarithm (base 10) of the opacity, which is the reciprocal of the transmission or reflection of a tone. (Field, 2004)

Gamma

The ratio of the contrast range of all or part of the reproduction to the corresponding contrast range of the original, see figure 35. A gamma of 1.0 means that the reproduction has the same contrast range as the original (Field 1999).

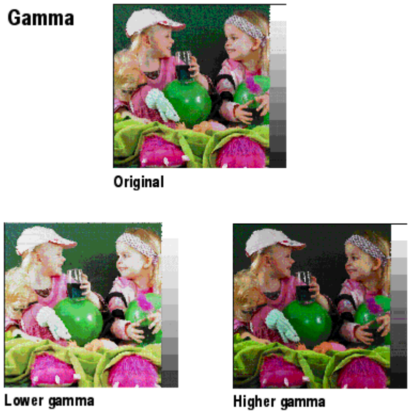

Figure 35: Example of lower and higher gamma (Enoksson, 2005).

GCR - Gray Component Replacement

GCR - a means of producing more consistent color and increased shadow detail in a printed reproduction by reducing the sizes of the cyan, magenta and yellow halftone dots that contribute to the darkening effect-or gray component-of an image. This has the effect of lightening an image without changing the actual colors reproduced, and the size of the black dots is increased to compensate for the gray removal (Romano, 1998).

International Color Consortium (ICC)

A committee formed in 1993 to establish specifications and guidelines for manufacturers and developers of software, equipment, and producers related to color management systems (Field, 2004).

IT.8

Information Technology, an ANSI-accredited committee that developed three standard targets for input and output profiling, collectively covered by Standard IT8.7:IT8.7/1, scanner transparency target; IT8.7/2, scanner reflection target; and IT8.7/3, CMY(K) output target (Adams, Weisberg, 2000)

JPEG (Joint Photographic Experts Group)
Data format and compression algorithm for color images. Often used in digital cameras (photography). Offers advantages for Internet applications due to the relatively small amounts of data involved.

MAC OS X
Mac OS X is an operating system used since 2004 by Macintosh-based computors (Johansson, Lundberg, Ryberg, 2006)

Subtractive color system - see also Color mixing systems
The subtractive color process is based on light reflected from an object and which has passed through pigments or dyes that absorb or "subtract" certain wavelengths, allowing others to be reflected. The primary subtractive colors - cyan, magenta, and yellow - can be combined to form red, green, and blue as secondary colors, see figure 36. Combining the ideal subtractive primaries in equal amounts produces black (Adams, Weisberg, 1998). CMYK (K = black = key color) is used for printing (output devices).

Figure 36:The primary colors are cyan, magenta and yellow and the secondary colors are red, green and blue.

Rendering Intents
When converting from RGB- to CMYK-mode in Adobe Photoshop, the user can decide which rendering intent to use: Perceptual, Saturation, Relative colorimetric, and Absolute colorimetric. The rendering intent decides how a colour management system handles the colour conversion from one colour profile (or gamut) to another.

Perceptual: The relationship between colors is retained. see figure 37. The perceptual rendering intent is used for photographic images with a very good result. The most pleasing result is mostly obtained if we do not distort the relationship between colors (Sharma, 2004).

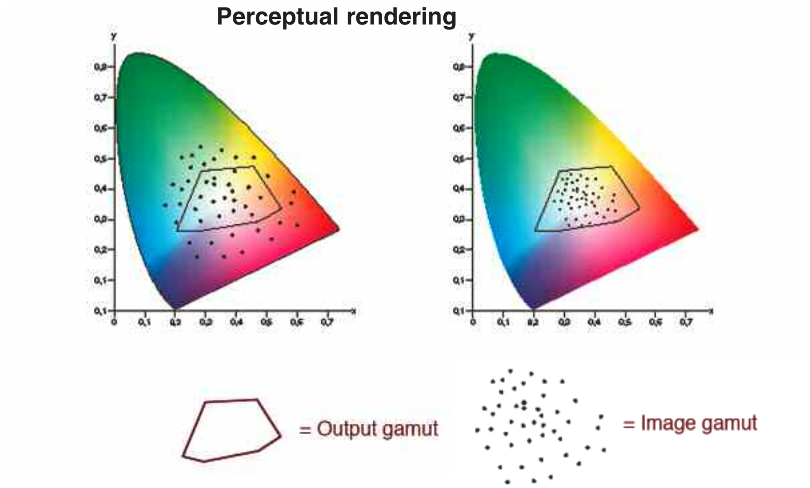

Figure 37: In perceptual rendering, the relationship betweem colors is retained .(Enoksson, 2005).

Relative rendering: With the relative intent, the colors outside the destination gamuts are clipped and forced to the gamut boundaries, see figure 38.

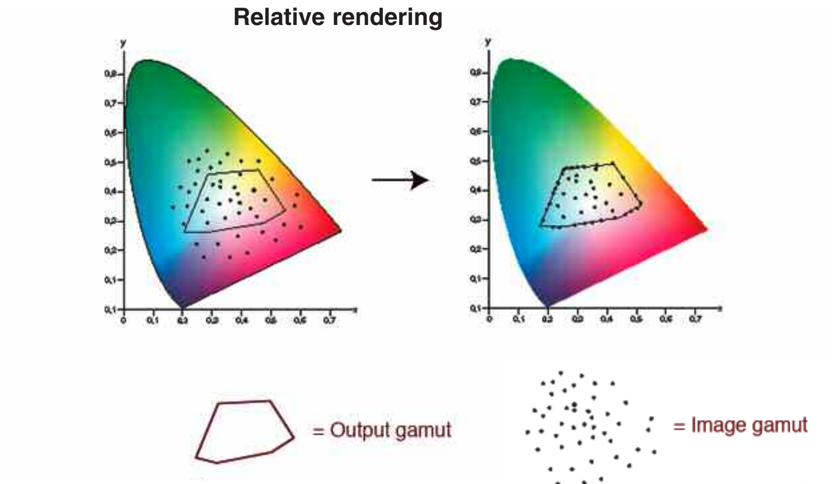

Figure 38: In relative rendering, the colors outside the destination gamut are cliped and forced to the gamut boundaries .(Enoksson, 2005).

In *absolute colorimetry* the white point in the image is not allowed to change.
In absolute colorimetry, the girl´s cap is yellow in the original and yellow in the reproduction. This intent is used in situations where we wish to make side-by-side comparison (Sharma, 2004). See figure 39.

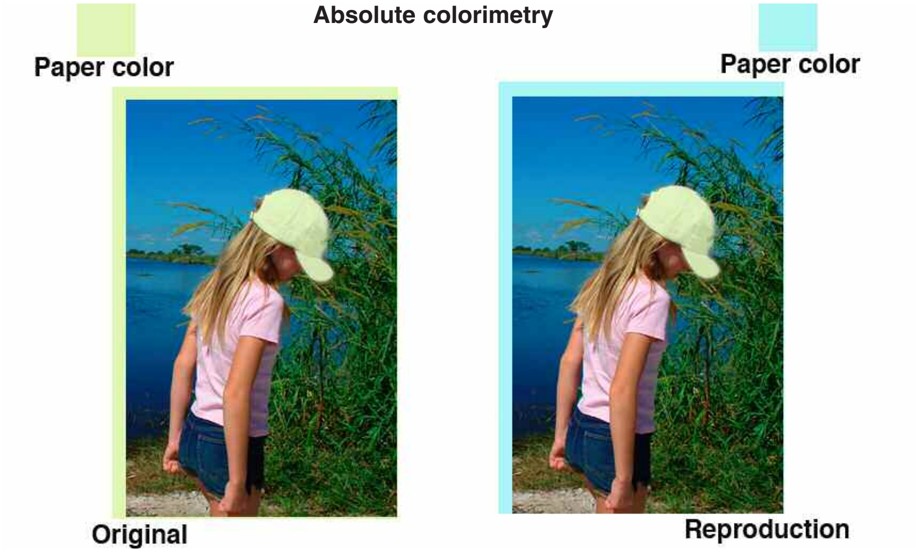

Figure 39: In absolute colorimetry, the white point in the image is not allowed to change. (Enoksson, 2005)

Relative colorimetry takes into account the white point of the destination substrate. In relative colorimetry, the white point is allowed to change. The original may have a yellow paper base, while the reproduction may be printed on a bluer paper stock. Using relative colorimetry, the girl´s cap is yellow in the original and blue in the reproduction (Sharma, 2004). See figure 40.

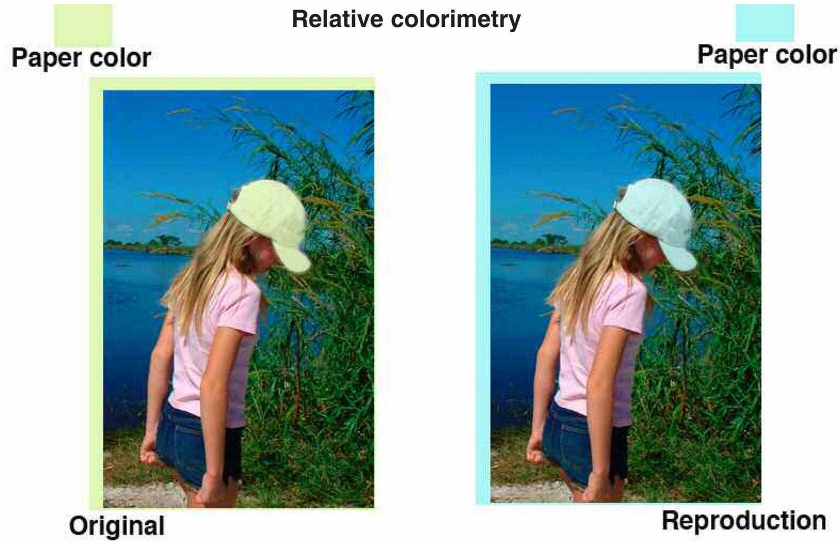

Figure 40: In relative colorimetry, the white point is allowed to change (Enoksson, 2005).

RGB - see Color mixing systems

Setoff
The undesirable transfer of wet ink to the following sheet in the delivery pile of a sheet-fed press.(Field, 2004)

TIFF (Tagged/or Tag Image File Format)
The most common pixel format; it is supported by virtually all systems. Among other things, this format is suitable for the data exchange of color images and gray values as well as various levels of resolution and sizes.

Tertiary color
In color printing, the color produced by overprinting secondary colors, or all three process colors. (Romano, 1998)

TIC - Total Ink Coverage,
Because process color ink pigments are imperfect, pure black cannot be achieved by overprinting CMY inks. Consequently, black (K) ink is introduced in addition to, or as a substitution for, CMY inks. The combined value of all CMYK inks for a particular area or object cannot exceed a specified amount, or ink may not transfer effec-

tively and printed sheets may not dry properly. This specified amount, referred to as the Total Area Coverage (TAC), is typically limited to 300% for offset lithography using coated paper. Compensation for TAC limitation is accomplished during the conversion from RGB to CMYK, by means of UCR (undercolor removal) or GCR (gray component replacement). http://dx.sheridan.com/advisor/tac.html

Trapping
The ability of an ink to transfer wet-on-wet, i.e. the ability of an ink to transfer equally well to both an unprinted substrate and a previously printed ink. (Field, 2004)

UCR - Under Color Removal
A technique used to reduce the magenta, cyan and yellow dot percentages in neutral areas and replace them with a suitable amount of black ink (Romano, 1998).

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