A Comparison of Print Quality between Digital and Traditional Technologies

Ole Norberg, Patrik Westin, Siv Lindberg***,
Marianne Klaman and Lars Eidenvall.*
DPC, Mid Sweden University, Örnsköldsvik, Sweden
**Framkom, Stockholm, Sweden,*
*** STFI, Stockholm, Sweden*

Abstract

The digital print technologies are advancing both in quality and market share. Today, the print quality of digital printed material has improved and is considered to bee good enough for most purposes. However, the great advantages of digital printing are short runs and variable data printing.

In this investigation the print quality of different digital printing technologies, today present on the market, are compared with the quality of traditional technologies such as offset and flexography. A wide range of digital presses, from large production presses to smaller devices for office use, was tested. The substrates used, were all chosen to fit the specific printing technology.

The print quality was evaluated by subjective evaluation as well as by technical measurements. To make the comparison of prints from different presses meaningful, color management has been an essential part of the process. An ICC-profile was created for each combination of substrate and press.

The results indicate that the offset print quality on fully coated paper is still ahead of what is possible to achieve with digital printing techniques today. This study shows that disturbance, like mottling and gloss variation, are the main shortcomings of the digital printing technologies. Another result, shown in this study, is the fact that digital printing is less sensitive to type of substrate.

Introduction

Digital printing made its major brake through in 1993. At about the same time, the work of International Color Consortium started and the introduction of color management by ICC-profiles were formed. Today, both the digital printing technology and the color management system have matured and the market acceptance is growing.

At first digital printing was only competing with short runs and the possibility of using variable data. Today, the printing technologies have been improved and new substrate has been developed to meet new demands.

Digital printing opens new possibilities. Products that earlier would not have been produced, can now easily be created with new technologies. Many recently presented reports[1,2,3] have shown a continuously growing trend for digital prints. It will therefor be an even more considerable player in the near future on the print market.

Material and Methods

Printing trials

The aim of this study was to achieve the highest possible print quality in each printing press used. Because of this, color management based on ICC-Profiles[4] was used. The printing trials comprise three phases:

- Print the test chart for the ICC-profile.
- Creation of ICC-profiles.
- Final print session with ICC-profiles.

Checklist
To guarantee consistent printing, a checklist was created. The checklist included descriptions of standardized printing conditions, such as climate control, print density and dot gain settings. The checklist was important while the printing trails took place at different places and in several steps.

Basis for the ICC-Profile
ICC-profiles were created for every combination of paper and printing press, altogether 43 different ICC-profiles. All profiles were created with the same software and instrument at Framkom.

A printing form including the TC 2.9 chart was printed; the TC 2.9 char is included in ProfileMaker Pro 3.0 used for the creation of the ICC-profiles. The TC 2.9 chart was measured with a Gretag Macbeth spectrophotometer (Spectrolino with measuring table). Photoshop 5.5 was used to apply the profiles on the images.

The liquid toner press and the offset press used ICC-Profiles created by the print shop it self.

Printing form
The printing form consisted of two A3-sheets. The first A3-sheet contained images for the perceptual study while the second sheet contained test areas for technical measurements of the print quality. An IT-8 test-chart was also included in the printing form. It was used to evaluate the influence of the ICC-Profile and for the purpose of evaluating reproduction of difficult colors.

Printing session
The printing session started when all the profiles were calculated. To maintain the printing conditions constant, the same consumable supplies were used in the print for ICC-profile and the printing with the profile applied.

The time interval between the both printing phases was kept as short as possible since the up-to-date of the ICC-Profiles was important. The test document was single-sided and printed on the primary side.

In order to eliminate the influence of printer, which was imperative, the presses were adjusted towards standard values for density and dot gain. Hence, the results should bee the same, irrespectively of how is running the press.

250 copies were printed at each single printing session, except for the Inkjet printer due to its lower productivity. For Inkjet printer about 50 copies were printed.

Evaluation

The print result has been evaluated in a visually perception study and by technical measurements of the prints.

Perception study

Two images with different motifs were used in the quality evaluation. One of the motifs was a still life "silverware", representing a low-key image with a homogeneous neutral grey background and silverware for reproduction of highlights, sharpness and gloss. The other motif was a portrait of a girl, representing a medium to high key image for reproduction of skin tones and fine details in hair and sweater. The samples were mounted, without an edge, by means of corner slips on a grey paper with Y-value 60, with two unprinted papers as backing.
The printed images were presented in a standard daylight[6,7] viewing equipment (Just Normlicht 5000) placed in a light grey painted experimental room illuminated with daylight-simulating light tubes (Philips TLD 36W/95, "Natural Daylight 5300"). The illuminance at the image location measured by a Hagner Universal Photometer Model S1 was 2000 lux with variations over the table from 1750 to 2000lux.

Proscale evaluation:
Twelve judges served in the experiment. Each judge was tested for colour vision with a simple test (Ishihara) and they had normal or corrected to normal vision. The judges were instructed to group the samples with respect to their similarity in print quality so that each group had some characteristic in common that separated them from other groups[8]. The judges were allowed to make as many groups as seemed appropriate. After the grouping was done, they assigned a rating to each group that corresponded to their perception of the quality of the samples in each group. Finally, the observers were asked to write down the number of the rating at or above which he or she found the samples acceptable to buy or to use.
Each judge served in two sessions; one for the image of silverware, and one for the portrait of the girl. The order of the sessions was balanced between the subjects in order to avoid training effects on the ratings.

Opinion-ratings:
Ten different judges served in this separate experiment. All of the panel members had normal or corrected to normal vision and were tested for color vision (Ishihara)
For each of the forty samples with the motif "Girl", thirteen print quality and print impairment attributes were evaluated[9]. They were: Overall print quality, color rendition, sharpness, contrast, detail rendition in highlight and shadow areas, color shift, gloss, mottle and print homogeneity.

A nine-point category scale was used for the evaluation. The scale ranged from 'excellent' to 'unusable' for the quality attributes and from 'not visible' to 'very annoying' for the impairment attributes. A reference Fuji films standard photograph of the girl was used in order to provide a reference.

Print quality measurement

101 different print quality parameters were measured on each print. The measurements were performed on specially designed test images in the testforms. Density was measured with a Gretag densitometer according to ISO 12647-1, color failure, and gray balance were measured by a Gretag SPM 100 spectrophotometer, according to ISO 13655:1996. Color gamut was measured with an Elrepho 2000 spectrophotometer. Edge sharpness and unevenness in the print, mottle in full tone and halftone, were measured on three different systems. All three systems were using flatbed scanners (Agfa Arcus) to capture the image. The images were then processed and analyzed. Gloss was measured according to Tappi and Ansi standard with a Zhentner gloss meter and a special designed device (developed at STFI) measuring small-scale gloss variation.

Multivariate data analyze

Because of the complexity and many dimensions of print quality, multivariate data analyze[10] was used to extract the most important parameters. With multivariate methods it is possible to obtain a mathematical expression of the response in terms of factors. Furthermore it is possible to look for groupings of objects or variables, and thereby get an indication of their influence.

By using traditional uninvariate methods to describe the relation between each factor and the response, instead of a multivariate method to describe the entire relation, you may loose a lot of information about how the interaction of the factors is affecting the response. An advantage with multivariate data analyze is also the possibility to identify and extract relevant parameters.

PLS-Partial Least Square
Partial Least Squares regression[11,12], or Projection to latent structures, is a relatively new method of performing regression analyzes. PLS is considered especially useful for constructing prediction equations when there are many variables and comparatively little sample data.

In this project the Extract software has been used for the multivariate data analyze and to create PLS (Partial Least Square) models.

Results

Evaluation of the ICC-profiles

Since the profiles were applied on the images, they will be the basis for the evaluation of the colour management.

Differences between the image reproductions on different printing presses were noticeable, but not obvious. The cheaper equipment could manage to produce a result that was not far away from what the more sophisticated printing presses produced.

It is important to know that the colour management founded up on ICC-profiles does not influence the colour gamut of a printing unit. However, it optimizes the result from its conditions. In this study, the color mapping method perceptual has been used. This method was used because the overall impression from the images should remind as much as possible of the original

Print quality measurement

The measurements that show the biggest difference between the different printing technologies are the measurements of uneveness in the print. All print quality parameters are improved in offset printing when a substrate of higher quality is used. In digital printing this effect is not that strong (*see figure 1*).

The color gamut, number of reproducible colors, are as god as or better than offset for all digital techniques. Especially the color copier and the Inkjet printer got large color gamut. The difference between uncoated and fully coated paper is negligible in the toner based technologies, while in offset, the gamut on fully coated paper is twice as large compared to the gamut on uncoated paper *(see figure 1*).

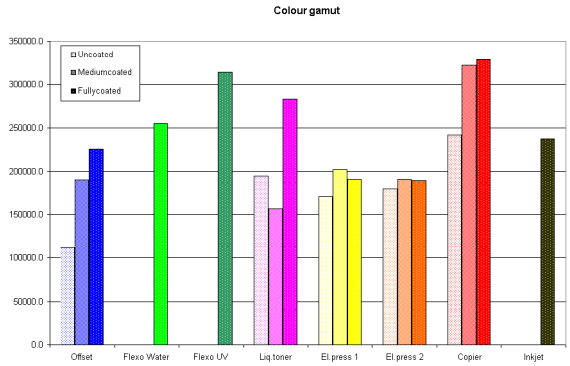

Figure 1: The color gamut of the different presses and substrates presented as number of reproducible colors.

Also the evenness of solid and screened areas improve tremendously in offset between different substrates. Inkjet, color copier and liquid toner press formed the most uneven screened (40% black) areas, while the toner-based presses and offset presses show better results (*see figure 2*).

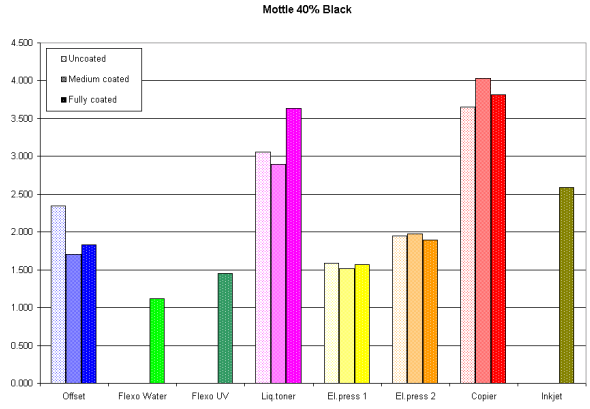

Figure 2: Mottle in screened, 40% black, area presented as variation (lower value better).

The toner based presses got their weakness in the reproduction of solid cyan and green areas (100% cyan and 100cyan +100% yellow respectively) (*see figure 3*).

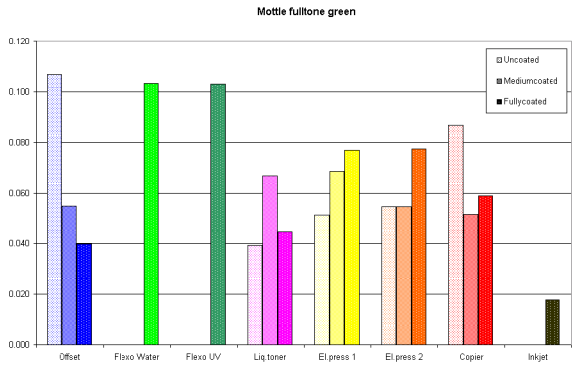

Figure 3: Mottle full tone green (100% cyan and 100% yellow). Presented as variation (lower value better)

The gloss levels of the prints from the toner-based systems are high but the small-scale variation of gloss level is a problem in the toner-based systems (*see figure 4*).

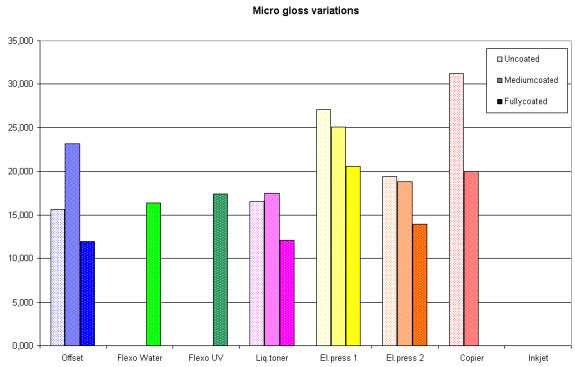

Figure 4: Micro gloss variations, presented as variation (lower value better)

Perception study

The plot of the preference ratings for "the girl" versus ratings for "silverware" show a somewhat linear trend, though somewhat scattered and quite a few observations lie off the diagonal (*see figure 5*).

In the figure, also each sample from the printing press is shown. Clearly, the characteristics of the presses influence the rating differently for the two motifs. The medium and uncoated samples printed in offset as well as the Flexo UV samples show a slightly better performance for the 'girl' than for the 'still life'. The samples printed on the copier and with liquid toner show an overall low performance in quality although maybe slightly better result for silverware. Interesting to note is that the electro photographic processes, although performing in the mid-quality range, appears to perform equally well on both images and also perform equally well on all paper grades from glossy to uncoated

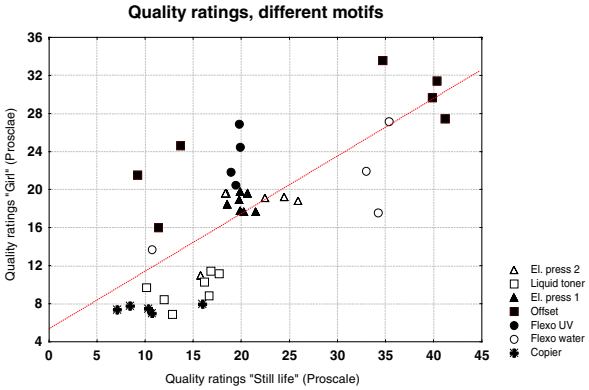

Figure 5: Quality ratings of two motifs ("girl" respectively "silverware") from the perception study. Higher value is better perceived quality.

Multivariate data analyze

The multivariate data analysis of both the technical measurements and the perception study show a difference between the different printing technologies. The technologies are arranged into groups in the score plot (*see figure 6*).

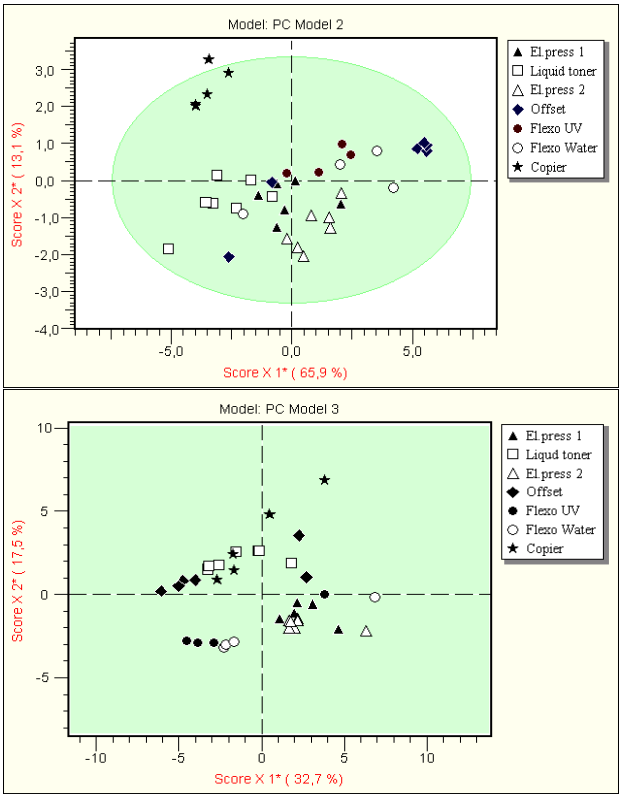

Figure 6: The multi variate data analyze show a difference between the different technologies in the data, the prints are grouped according to printing press in the score-plot The model based on perception attributes, top, and print quality measurements, bottom.

The prediction of two PLS models, based on the print quality measurements as well as the perception attribute are shown in figure 7. Both models are stable and describe the variations in the data. The model based on perception attribute explains the variation of the data better (81%) than the print quality measurements (77%). Also, the prediction capacity is better in the model based on the perception attribute (75%) compared to the model based on print quality measurements (62%). The prediction of the two models is showed in figure 7. The over-all print quality from the perception study is used as response in both models.

As shown in figure 7, the influence of substrate quality of the electrophotographical presses is modest. All samples printed by electrophotographical presses are agglomerated to the middle of the graph, while the offset printed samples are ordered along the diagonal; uncoated in the bottom left corner (lower print quality) and high-coated in the upper right (higher print quality).

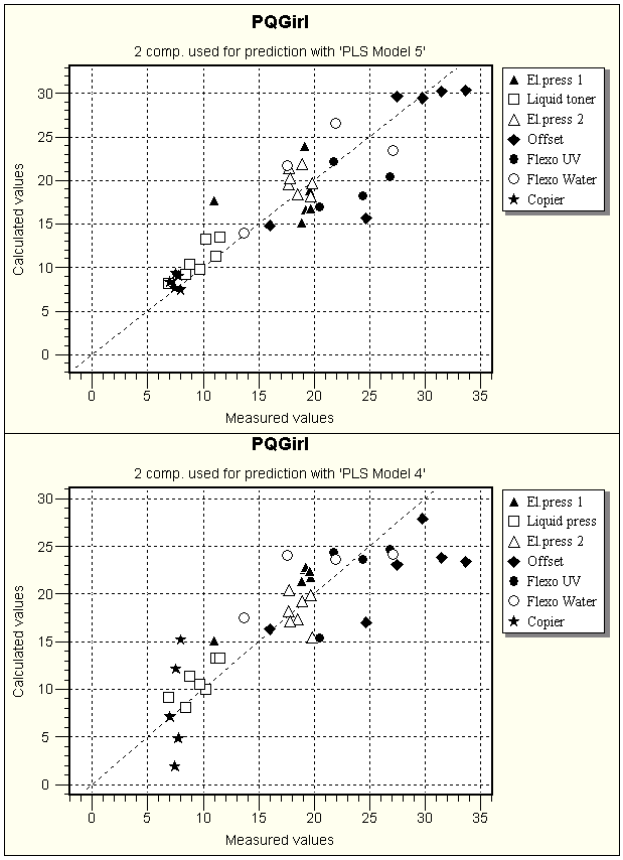

Figure 7: The prediction capacity of the two models based on print quality measurements respectively perception attribute.

Discussion

The purpose and ambition of the project was to optimize print condition, substrate and color management and thus eliminate all intervening variables so that real difference between technologies could bee observed. However, when it comes to color management it is not self-evident which software and procedure that will give the optimum result. In this case study, the choices made of which color management software to be used, were based upon the experience within the project group, as well as the equipment available.

The liquid toner printing presses and the color copier were not the newest models on the market. The liquid toner press has been in commercial use for a couple of years and is the most common type on the market today. The newer models of liquid toner presses are probably printing with a higher print quality.

Although color management has been used, small color differences can be discerned between the print samples. This difference in colors has maybe negatively affected the quality judgements in some cases.

Conclusion

The following conclusions can be drawn from the study:

- Offset print quality on coated paper is still ahead of what is possible in digital print technology today.
- Offset quality is to a large extent dependent on the paper quality.
- Electrophotographic quality is less dependent on the paper quality.
- The largest color gamuts were obtained in the color copier- and flexographic process.
- Mottle in halt-tone black was most noticeable in the color copier- and the liquid toner process.
- Full tone cyan was most uniform on the high-coated offset prints and least uniform on the uncoated offset prints as well as on the color copier and liquid toner prints.
- Micro gloss variation was most noticeable on color copier prints and uncoated offset prints and less noticeable on high-coated offset prints.
- The measurement of mottle in half-tone correlated most to perceived print quality.

References

1. Hancock, Mike, A digital future, Pira, Digital Print World Conference, 2001.
2. Graham, Michael J., Mass customization: creative marketing ideas for magazine and catalogue publishing, Pira, Digital Print World Conference, 2001.
3. Wilson-Higgins, Suzanne, The on demand digital model – making a business of it, Pira, Digital Print World Conference, 2001.
4. International color consortium, Specification ICC.1:1998-09.
5. GretagMacbeth, PostScriptum on Color Management, 1999.
6. ISO/DIS 3664, Photography-Viewing Condition-Photographic Prints, Photomechanical Reproduction and Transparencies, International Organization for Standardization, 1987.
7. ISO/DIS 12640, Graphical Technology-Prepress digital data exchange-CMYK standard color image data (CMYK/SCID), International Organization for Standardization, 1997.
8. Donderi, D.C., Information Measurement of Distinctiveness and Similarity, Perception and Psychophysics, 44(6), 1998, 676-584.
9. Donderi, D.C., Proscale 3.0 –Reference Manual. McGill University, Department of Psycology, and Pulp and Paper Research Institute of Canada, 1996.
10. Esbensen, K., Midtgaard, T., Schönkopf, S. *"Multivariate Analysis – in practice"*. Camo AS, 1994.
11. Garthwaite, P. H. "An Interpretation of Partial Least Squares". In "Journal of the American Statistical Association". Vol. 89, No 425 1994.
12. Geladi, P., Kowalski, B. R. *"Partial Least-Squares Regression: A Tutorial"*. In *"Analytica Chimica Acta"* **185**, 1-17.

Biography

The project "Testprint 2000" was co-operation between the three different Swedish research institutes
- The Digital Printing Center at Mid Sweden University
- Framkom, Research Corporation for Media and Communication Technology
-STFI, Pulp and Paper Research Institute

This combination covers the interests of printing technology, substrate and graphic art.

Suppliers from the Swedish Paper and bord industry have supported the project with knowledge and material.