

Measuring Register Shift and Investigating Its Effect on Color Appearance for Different Halftoning

Sasan Gooran*, Daniel Nyström*, Mahziar Namedanian*,
and Shahram Hauck**

Keywords: Misregistration, high-resolution camera, halftoning,
color appearance

Abstract

In commercial prints the halftone dots are seldom placed exactly at their corresponding positions in the digital bitmap, mostly due to the imprecise transportation of the printing substrate. In this study, we firstly present an image processing model to measure the displacement of the dots in different color separations by using a high resolution camera. By using a filter wheel equipped with a set of interference filters and sending light in different wavelength bands, it is possible to separate the different color inks. For example, for the combination of cyan and magenta inks, only cyan will be visible in the captured image if the wavelength band of the incoming light is concentrated around 700 nm. On the other hand, for the wavelength band concentrated around 500 nm only magenta will be visible. By comparing the positions of the dots in the captured images with those in the original bitmap we can measure register shift. Secondly in this study, we investigate how misregistration affects the color appearance of the final print for different halftoning techniques. We use AM, FM first generation and FM 2nd generation halftoning methods and investigate and compare their sensitivity to register shift.

* Department of Science and Technology, LiU Norrköping, Linköping University, Sweden

** manroland, Germany

In the present work we measure the register shift for color patches printed in offset by the proposed image processing model. In order to study the effect of misregistration on the resulting color appearance we first simulate the misregistration in the digital bitmap. Then we print the simulated bitmap using an office laser printer. Since the misregistration is usually negligible for digital prints, especially in lower resolution, we can examine the accuracy of our model for measuring dot displacement by comparing the simulated displacement with the measured one. Finally, by using a spectrophotometer to measure color coordinates, we can study the effect of misregistration on the resulting color appearance for different halftoning methods by calculating the ΔE_{lab} color difference.

Introduction

Due to the imprecise transportation of the printing substrate in commercial prints the halftone dots are seldom placed exactly at their corresponding positions in the digital bitmap (Hauck & Gooran, 2011). This will certainly cause some color shift in the final print result. In practice, it is impossible to predict the direction and the size of the register shift, which makes it impossible to compensate for the color shift caused by the register shift. In AM halftoning (four color printing), in order to reduce the impact of register shift, instead of only using one halftone angle, four different angles are used for the process inks, Cyan, Magenta, Yellow and Black. The reason is that when the same angle is used, the color dots are printed on top of each other (dot-on-dot) and a shift in position for one of the ink colors can move the print towards dot-off-dot, which can cause large color difference (Gooran, 2004). When the angles are different, the print is not dot-on-dot and a shift in position will possibly have smaller impact on the final color. FM halftoning on the other hand is believed to be less sensitive to the register shift because of the “stochastic” structure of the dots.

In this paper, we firstly present an image processing model to measure the displacement of the dots in different color separations by using a high resolution camera. Secondly, we investigate how misregistration affects the color appearance of the final print for different halftoning techniques, namely AM, FM first generation and FM 2nd generation.

Image Processing Tool to Measure Register Shift

In order to investigate the register shift in an offset print, we use a high-resolution camera with a field of view of (2.7x2 mm) and a resolution corresponding to 1.9 $\mu\text{m}/\text{pixel}$. The light source consists of a tungsten halogen lamp equipped with a set of seven broadband interference filters with center wavelengths band of 400 nm, 450 nm, 500 nm, 550 nm, 600nm, 650 nm, and 700 nm. More detailed descriptions of the experimental image acquisition are given in (Nyström, 2008) and (NAMEDANIAN et. al., 2011).

In the reflective wavelength band of an ink, the ink doesn't absorb the incoming light and the color-ink dots cannot be distinguished from the paper in the captured image. For example, for the combination of cyan and magenta inks, only the cyan ink will be visible in the captured image if the wavelength band of the incoming light is concentrated around 700 nm. On the other hand, for the wavelength band concentrated around 500 nm only magenta will be visible. This can be explained by Figure 1, which shows the reflective and absorbing wavelength bands of cyan and magenta. As seen in this figure cyan is transmitting while magenta is absorbing the incoming light at 500 nm. This means that in the captured image the magenta dots will not be visible if we use the interference filter at 700 nm. Due to the fact that the primary inks are not ideal, the cyan dots will still appear as shadows when using the interference filter at 500 nm, see Figure 2c.

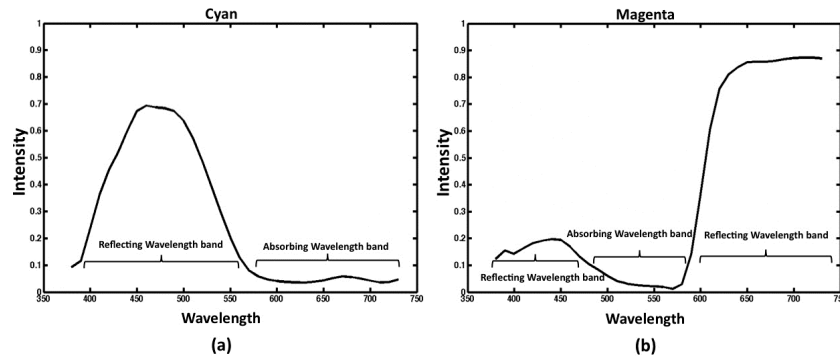


Figure 1. The reflectance spectra of cyan and magenta printed using commercial offset and coated paper.

Figure 2a shows the captured color image of a 10% AM halftone patch of Cyan and Magenta printed by commercial offset press (Heidelberg, 1200 dpi, 150 lpi) on coated paper (150 gr/m²). The cyan and magenta dots were placed on top of each other in the digital bitmap. Figure 2b shows the captured image using the interference filter at 700 nm, which means that the visible dots in this figure are cyan. Figure 2c shows magenta dots (and the “shadow” of cyan dots) using the interference filter at 500 nm.

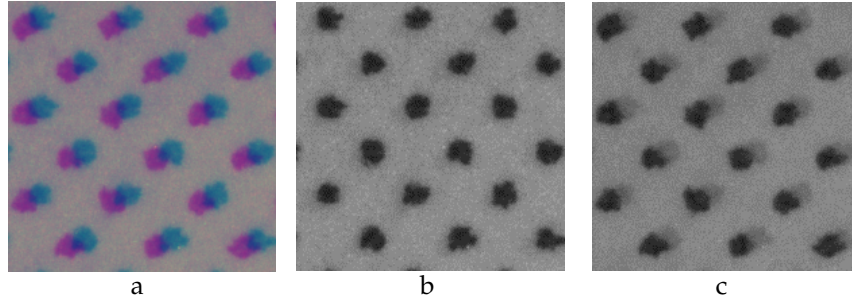


Figure 2. Captured image by a high-resolution camera a) 10% blue patch dot-on-dot in the original bitmap, the shift is because of the register shift. b) cyan dots, c) magenta dots and the shadow of cyan dots.

Since we know that the cyan and magenta dots are placed on top of each other in the digital bitmap any shift in position in the final print must have occurred during the printing process. In order to measure the shift we can find the center of the mass for cyan and magenta dots in Figures 2b and 2c. To do that we first need to threshold the images in these figures to separate the dots from the paper and the “shadow”, which can be done by using the histogram of these two images (NAMEDANIAN & GOORAN, 2010). By calculating the distance between the centers of the mass of cyan dots and those of magenta dots we can measure the displacement of the dots. Figure 3 shows the shifts in pixels in X and Y directions for six cyan dots relative corresponding magenta dots. Recall that a pixel in the captured images means $1.9 \mu\text{m}$. As can be seen in this figure the register shift is around 11 pixels ($20.9 \mu\text{m}$) in the X direction and around 5 pixels ($9.5 \mu\text{m}$) in the Y direction. Since the print resolution is 1200 dpi, this means that the register shift is around one printed dot in X and a half printed dot in Y direction.

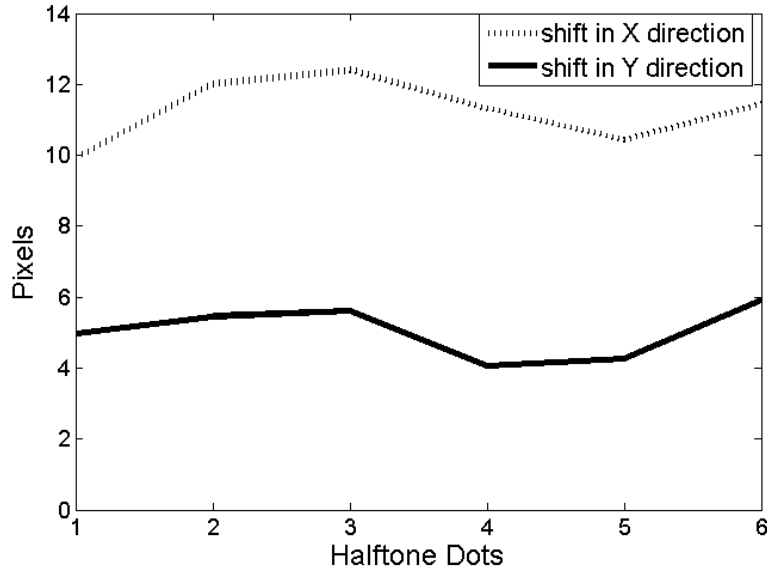


Figure 3. The register shift measured in pixels between cyan and magenta dots in X and Y directions for six halftone dots.

In order to test the proposed image processing method presented in this section we created a number of halftone patches of cyan and magenta and simulated a shift in the digital bitmap. The halftone patches were then printed at 300 dpi using a laser printer (Zerex Phaser, 6180). We shifted the magenta dots 5 pixels in both X and Y directions. We then captured images of the printed AM halftone patches (10% and 20%) by the high-resolution camera using a resolution of around $3.25 \mu\text{m}/\text{pixel}$. We separated the cyan and magenta dots as described in this section and found the centers of the mass. Since the register shift created by the laser printer at this resolution is negligible (which was also verified by capturing the halftone patches with no simulated shift), the measured register shift should actually be the same as the simulated shift. The calculated shift in pixels for both X and Y directions were around 130 pixels in the captured images, which means $130 \times 3.25 = 422.5 \mu\text{m}$. Recall that we had simulated 5 pixels shift, meaning $5 \times 25400/300 = 423.3 \mu\text{m}$ for 300 dpi. This test shows that our approach measures the register shift with a very high accuracy.

Halftoning and register shift

It is already known that register shift can cause color shift and Moiré pattern in AM halftoning when the same screen angle is used for Cyan, Magenta, Yellow

and Black. Therefore in four-color prints four different screen angles are used for the process inks, usually 0, 15, 45 and 75 degrees for Yellow, Cyan, Black and Magenta, respectively. The first generation of FM halftoning when the separations are halftoned independently is hardly sensitive to register shift. The reason is the fact that the dots are small and placed somewhat “stochastically” and the color channels are halftoned independently. Therefore any shift in positions will not have a great impact on the resulting color. When it comes to the second generation FM halftoning, where not only the frequency (number) of the dots is variable but also their size varies, one could guess the sensitivity to be somewhere between AM and FM first generation.

In order to carry out a thorough investigation on the sensitivity of different halftoning methods to register shifts we created halftone patches of cyan and magenta using AM, FM first and second generation. Figure 4a, b and c show a 20% halftone patch being halftoned by AM (at 15 degrees), FM first and FM second generation halftoning, here printed at 100 dpi for illustration purposes. In the case of AM, we both used the same angle of 45 degrees for cyan and magenta and also 15 degrees for cyan and 75 for magenta. In the case of FM first and second generation the cyan and magenta channels were halftoned independently. We simulated two different register shifts, two pixels and five pixels in both X and Y directions in the digital bitmap. These shifts correspond to 169 and 423 μm as the patches are printed at 300 dpi. We then used a spectrophotometer to measure the CIELab values for the printed halftoned patches with and without simulated register shift. By calculating the ΔELab color difference between the color of each patch before and after simulated register shift we can determine how sensitive different halftones are to register shift. Totally 33 different patches with different coverage for cyan and magenta were printed. Table 1 and 2 illustrate the ΔELab caused by register shift of 2 and 5 pixels, respectively.

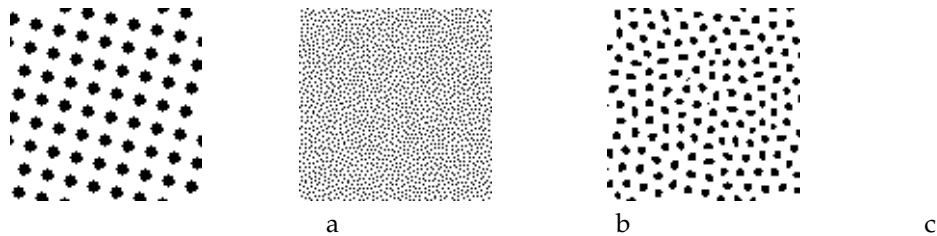


Figure 4. A 20% halftone patch printed at 100 dpi, halftoned by a) AM halftoning (15 degrees), b) first generation FM halftoning, c) second generation FM halftoning.

These results show that, as expected, the first generation FM halftoning when the color separations are halftoned independently is not sensitive to register shift. The small ΔELab for this halftoning can be partly due to the inevitable measurement errors. The FM second generation is, as expected, more sensitive

to register shift but more shifts in position doesn't necessarily lead to larger ΔE_{Lab} color differences, which is also valid for AM halftoning. Using different angles in AM halftoning does not either necessarily decrease the color difference. Due to the periodical structure of the halftoned dots in AM halftoning a small shift in position can sometimes lead to larger color difference than a larger shift. The two tables clearly show that AM halftoning is very sensitive to register shift and using different angles doesn't help in all situation as much as one would expect in some cases.

Table 1. The color difference ΔE_{Lab} caused by register shift of 2 pixels in both X and Y directions for different halftoning.

	AM (same angle)	AM (different angles)	FM 1st	FM 2nd
Average (ΔE_{Lab})	4.92	5.09	1.62	3.11
Max (ΔE_{Lab})	10.42	10.88	3.09	6.04

Table 2. The color difference ΔE_{Lab} caused by register shift of 5 pixels in both X and Y directions for different halftoning.

	AM (same angle)	AM (different angles)	FM 1st	FM 2nd
Average (ΔE_{Lab})	6.29	4.16	1.68	2.65
Max (ΔE_{Lab})	17.57	12.47	4.02	7.83

Conclusions

In this paper we presented a new approach to measure the register shift. The approach was then examined by measuring the simulated register shift for halftone patches printed by a laser printer. The test showed that the proposed approach can measure the register shift with a very good precision. Patches with simulated register shift was then created and printed by a laser printer. The effect of register shift was then measured by color difference ΔE_{Lab} for different halftoning methods, AM (same angle for cyan and magenta), AM (different angles for cyan and magenta), FM first and second generation. The results show that both AM methods are very sensitive to register shift while FM first generation is almost not sensitive at all. In comparison with the AM methods the second generation FM halftoning is not either so sensitive to register shift.

References

- Gooran, S.
 2004, "Dependent Color Halftoning, Better Quality with Less Ink,"
 Journal of Imaging Science & Technology, Volume 48, Number 4, pp.
 354–362, July/August 2004.

- Hauck, Sh., and Gooran S.
2011 "An alternative method to determine the register variation using Spectrophotometry," Proceedings of Technical Association of Graphic Arts (TAGA).
- Namedanian, M., Gooran, S.
2010 "High Resolution Analysis of Optical and Physical Dot Gain," Proceedings of Technical Association of Graphic Arts (TAGA), pp 48–51.
- Namedanian, M., Gooran, S., Nyström, D.
2011 "Investigating the Wavelength Dependency of Dot Gain in Color Print," IS&T/SPIE, Electronic Imaging Sci. Technol., 7866, No. 786617.
- Nyström, D.
2008. "High Resolution Analysis of Halftone Prints—A Colorimetric and Multispectral Study," Dissertations No. 1229, Linköping University.