Densitometric and Planimetric Measurement Techniques for Newspaper Printing

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Abstract

Two types of measurement technologies are used for process control in newspaper printing, namely densitometric and planimetric technologies. Densitometric measurements are done with densitometers or spectrophotometers, while planimetric measurements are typically done with CCD image sensor-based instruments called dot meters. Although these two technologies are fundamentally different, they are often used interchangeably in print calibration and process control. In this paper we investigate the statistical relationship between densitometric and planimetric measurements on newspaper print.

The aim of our project was to investigate whether it was possible to estimate halftone values measured by a densitometer, from the halftone values measured by different dot meters. The applied model is based on regression analysis using second order polynomials. The results are given as estimates of the polynomial parameters, i.e. the polynomials give the relation between halftone measurements with one of the dot meters and halftone measurements with the densitometer.

Our statistical analysis showed that due to the large uncertainty of the estimated parameters, the model does not accurately describe the relationship between the two measurement technologies. This can be explained in part by the poor repeatability performance for dot meters applied to newspaper print. Moreover the measurement results also have shown significant variations within the three dot meters used in this experiment. Factors affecting the repeatability and determining the performance of the model are considered and discussed in this work.

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Introduction

In newspaper printing essentially two types of measurement technologies are used for process control, namely densitometric and planimetric measurements. In densitometric measurements, the optical density is measured, and if needed converted to halftone values, typically using the Murray-Davies equation. In planimetric measurements, it is attempted to directly measure the halftone values, that is, the dot area coverage, typically using devices containing a CCD imaging sensor; such devices are often called dot meters. Although these two technologies are fundamentally different, they are often used interchangeably in print calibration and process control.

This raised a question: "Is there a relation between halftone measurements with densitometers (converted into halftone value with the Murray-Davies-equation) and halftone measurements with dot meters on newspaper print?"

In this paper we investigate the statistical relationship between densitometric and planimetric measurements on newspaper print. The objective of this study is to find out whether it is possible to convert planimetric halftone measurements into densitometric halftone measurements and vice versa. Since these technologies are used interchangeably, it is important to know how to convert from planimetric measurements into densitometric measurements, to keep the printing process under control and to achieve high print quality.

This study is limited to newspaper printed in coldset offset lithography using AM-screening. The test-target is printed in three different printing devices with different process parameters. Factors that possibly could have affected the final print (like printing parameters) are considered as "noise" and will not be discussed. Our focus is to find whether there is a statistical relationship between densitometric and planimetric measurements on newspaper print independent of factors that possibly could have affected the printing process.

This study also includes repeatability analysis for the measuring devices; three dot-meters and one densitometer. It is necessary to know the repeatability of the measuring devices, to indicate the validity of a possibly relationship.

After giving a brief overview of the different measurement technologies and state of the art, we present our experimental setup, preliminary pre-tests, experimental results and finally summary, conclusions and perspectives.

Measurement technologies

The size of the halftone dots increase during the printing process. This is called dot gain. It is important to know the dot gain characteristics to achieve high print quality. The dot gain is divided into mechanical and optical dot gain. Mechanical dot gain is the result of growth during the printing process (Malmqvist et al, 1999). Optical dot gain appears due to absorption and light scattering in the ink and the paper. This makes the dots seem larger and darker than they really are. The sum of mechanical dot gain and optical dot gain is called total dot gain.

Density is the light absorbtion ability of a material. The measurement of density is done with an instrument called a densitometer and is used to control colours in the printing process. Density is given by:

$$D_{ink} = \log_{10} \frac{I_i}{I_m},$$

where I_m is the reflected light intensity and I_i is the intensity of the incident light (Bergman, 2005). High density corresponds to high absorption.

A reflection densitometer measures the amount of reflected light from a surface. It consists of a light source to illuminate the sample, optics to focus the light, filters to define the spectral response of the sample and a detector to monitor the reflected light. The sample is viewed at 45 degrees from the surface. The reflected light is then converted to density with a logarithmic amplifier and displayed digitally. The densitometer sees the dot almost like the human eye and provides an optical density value (Tobias Associates, 2007)

Murray (1936) expressed the relationship between the reflection density of halftone prints and the dot area R, known as the Murray-Davies equation:

$$R = \frac{1-10^{-D_R}}{1-10^{-D_H}} \times 100\%,$$

where D_R is the density for a sample and D_H is the solid ink density.

Traditionally halftone dot area measurements have been done in laboratories with an instrument called a planimeter (Romano, 1996). This is the same as an image analyzer. In planimetric measurements, the dot area coverage is measured by using devices containting a CCD imaging sensor. Such devices, designed for measuring printing plates, are often called dot meters. A dot meter combines a microscope and a CCD imaging sensor. According to Romano (1996) the major variables in a system like this are image capture, aperture selection and thresholding. The dot meter analyzes the digital image and decides what is a part of the dot and what is not based on a threshold. The camera takes a snap-shot of the area being measured and literally counts the number of black and white pixels in the image. The dot meter is actually measuring the dot area and provides an absolute value of dot coverage (Colthorpe and Imhoff, 1999).

The focus of the camera is an important factor. The depth of focus is typically less than 0.2 mm for any such system (Colthorpe and Imhoff, 1999). The dot meter uses the image histogram and a threshold to calculate dot area. The threshold defines how dark a pixel should be to be taken into account.

Literature review

In the past, several studies regarding dot meter and densitometer measurements have been done; considering their reliability for different materials (Colthorpe and Imhoff, 1999; Hsieh et al., 2003), comparisons of the two measurement technologies (Spotts et al., 2005; Hsieh et al., 2003) and the use of an image analysis system to measure density (Malmqvist et al., 1993; Brydges et al., 1998). Most of these studies deal with measurement of printing plates. However, lately densitometers and dot meters are used interchangeably and not only for printing plates, but also on newspaper print (Aasen et al., 2002; NADA, 2007).

Yule and Nielsen (1951) studied whether halftone values from density measurements corresponded to real dot areas. They found that halftone value calculated from density values with the Murray-Davies equation did not correspond to the real dot area coverage, because the effect of the penetration of light into the paper is usually neglected. Especially for uncoated papers the density of middle tones increases and multiple internal reflections from the paper surface increase it still further, so that the usual simple equation relating dot area to density is not accurate. Their general conclusion is that the relationship between dot area and halftone density is not nearly as simple as it appears.

Arnaud (2001) compared three methods of image analysis to determine the physical area of dots on five different substrates, among these uncoated paper and printing plates. The three devices were all based on an optical microscope. His conclusion was that the dot gain (mechanical and optical dot gain) is a parameter at least as important as the solid ink density in process control. Arnaud states that an image analysis software needs to be created specifically for the printing industry and that this software should be able to accurately measure dot area on any substrate (including papers).

Romano (1996) states that measuring halftone dot areas on printing plates with a video image analyzer is a simple procedure, but tends to be rather subjective. It is very important to obtain a high quality image. According to Romano, the image quality is dependent of two criterias; the distance between the histogram's peaks (contrast) and the depth of the histogram valley (sharpness) of the 50%

tint. Illumination is also an important factor. When it comes to size of aperture (field of view), Romano states that this is a critical factor to make accurate measurements. With small aperture size (enclosing only a few dots), errors can occur when the aperture is randomly placed.

Experimental approach

As mentioned previously the aim of this study is to find out whether it is possible to convert planimetric halftone measurements into densitometric halftone measurements. Hence, a specific test target consisting of 16 patches (patch size 8x8mm) in different halftone values for each process colour (CMYK), was designed (Table 1 and Figure 1). The target was printed in coldset web-offset lithography using AM-screening, in three different printing plants (three different Norwegian newspapers), namely Bladet Sunnhordland, NR1 Trykk, and Orkla Trykk. In the following, the test targets are referred to with the name of the printing plant and a number indicating the sequence number of the copy. For instance, the test-target used as training-set is referred to as "NR1 Trykk 24000".

As densitometer, a GretagMacbeth Spectrolino spectrophotometer was used, under the following setup: Physical filter: Pol, White base: Paper, Illuminant: D65, Observer angle: 2º, Density standard: DIN NB. Three commercially available dot meters were used in this study (brand names withheld for anonymity).

Given the halftone values measured by one of the dot meters, the aim was to predict halftone values of the densitometer. The applied prediction model is based on regression analysis using second order polynomials. The results are given as estimates of the polynomial parameters, i.e. the polynomials give the relation between halftone measurements with one of the dot meters and halftone measurements with the densitometer, as follows:

$$y_{densitometer} = ax^2_{dotmeter} + bx_{dotmeter} + c$$

In polynomial regression, it is important to avoid over-fitting. Graphs with measurement data indicated that the relation could be described with second order polynomials; the scatter plots showed slowly decreasing graphs. Third order polynomials were also investigated, but the third order terms were extremely small. Hence, the polynomials used are second order to avoid over-fitting, for details, refer to Wroldsen (2006).

Two limitations of the model were introduced; if the predicted densitometer value exceeds 100% or is below 0%, the value is clipped to 100% and 0%, respectively.

Empirical correlation coefficients (Løvås, 1999) were calculated to indicate whether a relationship exists between the measurement datas:

$$r = Correl(X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

C100%	C97%	C89%	C81%	C73%	C65%	C58%	C55%
C50%	C45%	C40%	C32%	C24%	C16%	C8%	C3%
M100%	M97%	M89%	M81%	M73%	M65%	M58%	M55%
M50%	M45%	M40%	M32%	M24%	M16%	M8%	M3%
Y100%	Y97%	Y89%	Y81%	Y73%	Y65%	Y58%	Y55%
Y50%	Y45%	Y40%	Y32%	Y24%	Y16%	Y8%	Y3%
K100%	K97%	K89%	K81%	K73%	K65%	K58%	K55%
K50%	K45%	K40%	K32%	K24%	K16%	K8%	K3%

Table 1. Digital halftone values (as specified in the image file) for the test target used in this study (see Figure 1).

Figure 1. The test target.

Because of significant measurement differences between the process colours, it was necessary to study each of them individually. Furthermore the measurement data were divided into two sets; a training set to establish the model and a test set to evaluate its performance. The residuals between the predicted and measured halftone values with the densitometer (with test set = training-set and test set ≠ training set, respectively) were used to judge the performance of the model.

Because of significant measurement differences between the dot meters and also between the process colours for each densitometer-dotmeter-combination, it was necessary to study both the instrument combinations and the process colours individually (Wroldsen, 2006). The modelling and data analysis were therefore conducted separatly for each dot meter.

The following method was used in this study to build and test the model (describing a possibly relationship between densitometric and planimetric measurements) for each combination of instruments: 1) Three series of measurement data from one test target were used to establish the model (one model for each process colour). This measurement data makes the training set. 2) The residuals between predicted and measured halftone values with the densitometer (with the test set being part of the training set and with the test set totally independent of the training set, respectively) were used to judge the performance of the model. Some of the test targets in the test set were printed in another printing plant than the test target of the training set.

Preliminary repeatability tests

To justify that the densitometer could be used as a reliable representative for all densitometers, we did a preliminary test with two different densitometers. This was done to verify whether different densitometers give the same result (in contrast with the dot meters which are based on thresholds). For this test we used the test-target named “Bladet Sunnhordland 1500”. The following patches were measured for each process colour: 100%, 81%, 50% and 24% (white base: paper).

The density values were converted to halftone values using the Murray-Davies-equation, and the densitometer pretest showed the largest deviations for halftone values below 24%. This is probably caused by the conversion from logarithmic density values into halftone values. Low density values converted to halftone values using the Murray-Davies equation result in larger variations than high density values. This effect is getting even more obvious with low solid ink densities, like in newspaper printing. Another critical factor is the number of decimals used for density measurement. Even though the densitometer pretest showed some deviations between the two densitometers, only one of them is used in the analysis. This was necessary to limit the analysis.

The repeatability analysis of the densitometer was satisfying. We measured the 50% patch 10 times. The variation was less than 0.01 density for all the process colours. The tolerance density deviation for densitometer measurements is ±0.01 according to DIN 16536-2 (1995).

A repeatability analysis was also conducted for the dot meters. On newspaper print the 50%-patch for each process colour (CMYK) was measured 10 times with each dot meter. Based on these measurements, we calculated the average, range (absolute value of maximum halftone value minus minimum halftone value) and standard devation were for the three dot meters on newspaper print (note: not printing plates). The repeatability analysis showed low repeatability for all three dot meters, as shown in Table 2, 3 and 4.

Dot meter 1	**Test-target: "NR1 Trykk 24000"**			
	C50%	M50%	Y50%	K50%
Average	49.70%	46.35%	47.50%	41.05%
Range	3.00%	3.00%	3.50%	1.00%
Standard deviation	0.92%	1.11%	1.00%	0.28%

Table 2. Repeatability analysis – dot meter 1.

Dot meter 2	**Test-target: "NR1 Trykk 24000"**			
	C50%	M50%	Y50%	K50%
Average	48.86%	48.25%	52.53%	39.69%
Range	5.80%	6.10%	7.00%	2.80%
Standard deviation	1.90%	1.67%	1.91%	0.95%

Table 3. Repeatability analysis – dot meter 2.

Dot meter 3	**Test-target: "NR1 Trykk 24000"**			
	C50%	M50%	Y50%	K50%
Average	49.15%	42.25%	47.80%	40.40%
Range	4.00%	3.50%	2.50%	2.00%
Standard deviation	1.49%	0.98%	0.86%	0.57%

Table 4. Repeatability analysis – dot meter 3.

DIN 16536-2 (1995) states the tolerance variation of density measurements to be ±0.01. However, there is no standard dealing with acceptable variations for dot meter measurements. In accordance with ISO 12647-3 (2005) the optical density for CMY should be 0.9 and for black 1.1. Outside U.S the 26% tonal value curve is used. This means that the tone value increase at 40% or 50% should be

26%. Optical solid density 0.9 and 26% tone value curve make ±0.01 correspond to approximately 2% tone value for the middle tones (see Table 5). None of the three dot meters fulfilled this requirement.

Density		Murray-Davies
D_H	D_R	Halftone value
0.90	0.90	100.0%
	0.48	76.52%
	0.47	75.64%
	0.46	74.73%

Table 5. Tolerance tone value for the middle tones.

According to the presented results, it is not possible to decide whether this low repeatability is caused by the measuring devices and/or inhomogeneous halftone values within one patch. Print irregularities cause noticeable differences in measured halftone values and reduce the repeatability when the aperture is small. Large screen dots used in newspapers in combination with small aperture is therefore unfavorable. It is not unambiguous to decide what is substratum and what is part of a screen dot, especially for middle halftone values, due to high optical dot gain (see Figure 2).

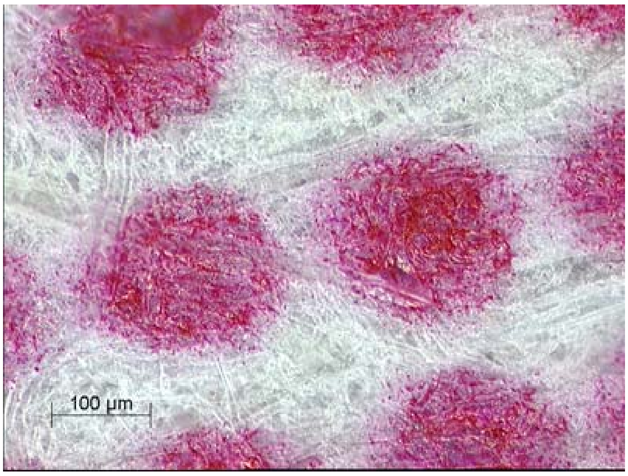

Figure 2. Image of a 50% halftone value printed on newspaper with magenta ink taken with a Zeiss Axioplan 2 imaging microscope by Maria S. Wroldsen.

Experimental Results and Discussion

The calculation of empirical correlation between the densitometer and dot meter values indicated relationship (see Table 6). Due to the fact that the correlation coefficients were close to 1, it can be assumed that there must be a correlation between the halftone values measured by the various instruments.

	Dot meter 1	Dot meter 2	Dot meter 3
Densitometer, C	0.984	0.986	0.979
Densitometer, M	0.991	0.984	0.982
Densitometer, Y	0.988	0.997	0.991
Densitometer, K	0.986	0.983	0.985

Table 6. Empirical correlation coefficients

Based on three measurement series of one test target, second order polynomials estimating the relationship between halftone measurements with the dot meters and the corresponding halftone measurement with the densitometer were established.

Figures 3, 4, 5 and 6 show measurement data with belonging trendlines for the three measurement series with dot meter 1, of the test target “NR1 Trykk 24000”; this constitutes the training set for our model. These graphs show that the trendlines highly fit the measurement datas. To test this model, we calculated residuals between predicted and measured halftone value.

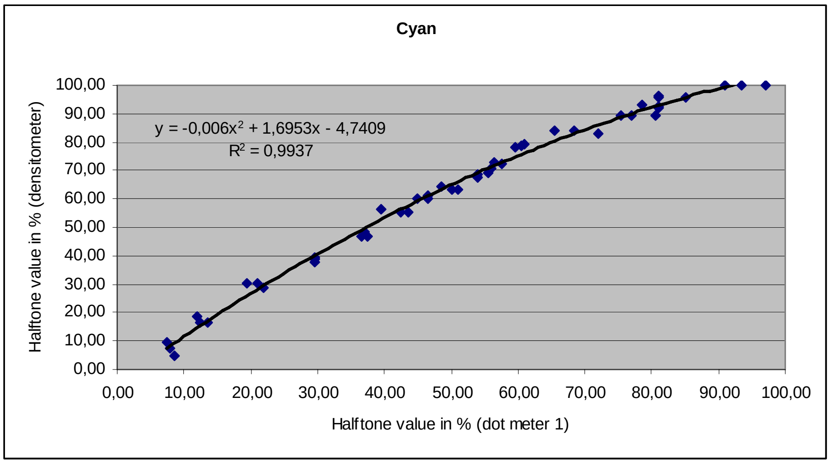

Figure 3: Relation for cyan (“NR1 Trykk 24000”, dot meter 1)

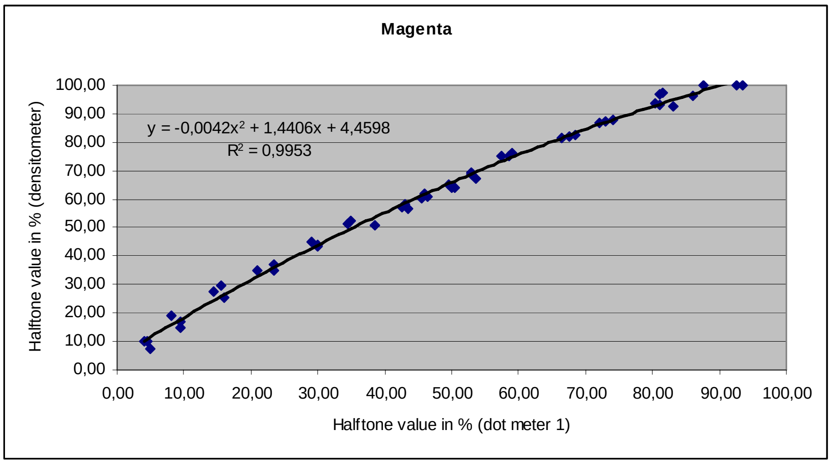

Figure 4: Relation for magenta ("NR1 Trykk 24000", dot meter 1)

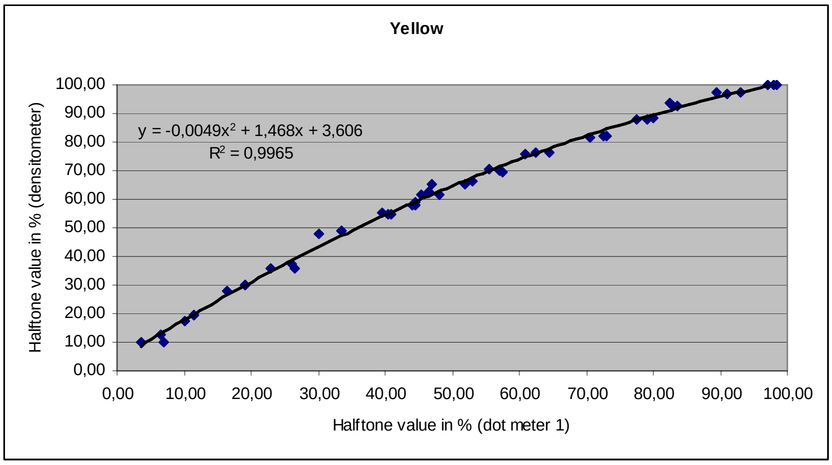

Figure 5: Relation for yellow ("NR1 Trykk 24000", dot meter 1)

The residual between predicted and measured halftone value with the densitometer was calculated as in the following example with cyan 65%:

- Measured halftone value with dot meter 1: 59.50%
- Measured halftone value with the densitometer: 78.12%
- Predicted halftone value with the densitometer: 74.89% (relation for cyan; $y = -0.006x^2+1.6953x-4.7409$)

The residual between measured and predicted halftone value with the densitometer: 3.23%

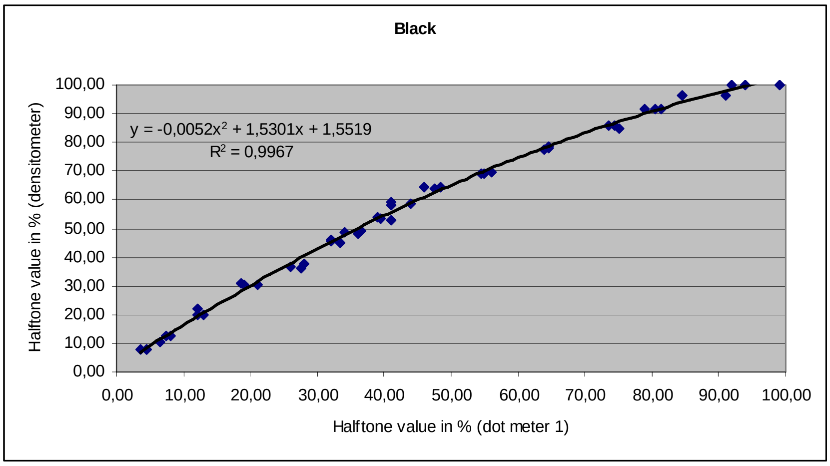

Figure 6: Relation for black ("NR1 Trykk 24000", dot meter 1)

Table 7 shows residuals when test-set is part of training-set. Because the test set is part of the training set, it is expected that the differences between the predicted and measured halftone values are rather small. As it can be seen in Table 7 the variations are colour and halftone value independent and does not follow a certain trend although cyan shows the largest variations. However, there is no significant trend for the obtained variations. Although the model performs well it is important to test the model with another test-set.

Table 8 shows the residuals when test-set is not part of training-set. It can be seen that the model does not perform that well applying another test-set. Consequently the differences between the predicted and measured halftone values are larger. Although the residuals have increased, the variation still does not follow a certain trend.

Residuals between predicted and measured densitometer values were calculated for several test sets different from the training set. Some of these test-sets where printed in different printing processes than the training-set.

As stated earlier, 2% can be considered the tolerance variation for dot meters. Some residuals are larger than 2% and this indicates that the model is not good enough to describe a relation. The low repeatability is an unfavorable factor.

	Residuals			
Patch	**Cyan**	**Magenta**	**Yellow**	**Black**
100%	0.00	0.00	0.10	0.00
97%	0.13	0.14	0.14	1.54
89%	1.20	1.13	0.85	0.58
81%	3.63	1.61	1.50	0.58
73%	3.23	0.92	0.97	0.04
65%	3.23	2.62	0.87	0.68
58%	0.79	1.33	1.53	0.99
55%	1.60	1.68	3.59	3.73
50%	1.47	0.15	1.49	0.35
45%	0.95	1.86	0.84	1.30
40%	1.19	2.01	1.18	0.37
32%	2.09	0.11	4.46	1.20
24%	0.78	1.00	0.97	2.66
16%	0.98	1.36	1.51	0.83
8%	0.55	3.77	0.53	0.82
3%	4.25	4.87	1.52	1.09

Table 7. Dot meter 1, densitometer: Residuals in % when the test set is part of the training set. (Test set: "NR1 Trykk 24000", 1. measurement series.)

	Residuals			
Patch	**Cyan**	**Magenta**	**Yellow**	**Black**
100%	0.00	0.00	0.00	0.00
97%	2.15	1.59	1.66	0.94
89%	2.12	3.24	1.86	3.16
81%	3.25	5.83	2.15	1.46
73%	4.38	5.57	3.78	3.71
65%	5.04	0.40	3.82	4.99
58%	4.82	1.46	4.17	6.04
55%	3.65	0.78	4.07	4.85
50%	1.06	2.66	2.64	1.0
45%	0.16	1.48	4.51	1.75
40%	1.45	1.64	3.99	2.43
32%	2.61	5.86	1.69	1.54
24%	4.55	5.52	3.43	3.07
16%	2.60	2.19	0.59	1.01
8%	0.17	4.09	0.37	0.72
3%	4.91	1.80	4.66	0.48

Table 8. Dot meter 1, densitometer: Residuals in % when the test set is different from the training set. (Test set: "Orkla Trykk 5000".)

We have so far presented and the detailed results from the first dot meter only. In the following we summarize briefly the results for the two other dot meters, for more detailed information refer to Wroldsen (2006).

For dot meter 2 the obtained regression polynomials are shown below. The residuals are larger when test-set is different from the training-set (see Table 10) than for test-set part of training-set (see Table 9) and indicates that our second order polynomials do not satisfactory describe a possibly relationship between halftone measurements with dot meter 2 and the densitometer. This is partly caused by the low repeatability for dot meter 2.

$$\text{Cyan}: \quad y_{densitometer} = -0.0061x_{dotmeter2}^2 + 1.6114x_{dotmeter2} - 2.0895$$
$$\text{Magenta}: \quad y_{densitometer} = -0.0051x_{dotmeter2}^2 + 1.5363x_{dotmeter2} + 1.092$$
$$\text{Yellow}: \quad y_{densitometer} = -0.0018x_{dotmeter2}^2 + 1.0991x_{dotmeter2} + 7.1581$$
$$\text{Black}: \quad y_{densitometer} = -0.0063x_{dotmeter2}^2 + 1.6296x_{dotmeter2} + 0.3169$$

	Residuals			
	Cyan	**Magenta**	**Yellow**	**Black**
Max	5.88	4.11	3.73	4.80
Average	2.27	1.29	1.54	1.32

Table 9. Dot meter 2, densitometer: Residuals in % when the test set is part of the training set. (Test set: "NR1 Trykk 24000", 1. measurement series.)

	Residuals			
	Cyan	**Magenta**	**Yellow**	**Black**
Max	4.37	8.39	6.87	6.87
Average	2.09	3.65	2.63	2.35

Table 10. Dot meter 2, densitometer: Residuals in % when the test set is different from the training set. (Test-set: "Orkla Trykk 5000".)

The polynomials for dot meter 3 is are given below, and the residuals are given in Table 11 and 12. We see the same trend as for the two other combinations of instruments. The average residuals are larger when test-set is not part of training-set. As for the two other combinations, the low repeatability of the dot meter is one factor that makes our model unsatisfactory.

$$\mathit{Cyan}: \quad y_{densitometer} = -0.0049x_{dotmeter3}^2 + 1.3198x_{dotmeter3} + 13.486$$
$$\mathit{Magenta}: \quad y_{densitometer} = -0.0044x_{dotmeter3}^2 + 1.3316x_{dotmeter3} + 10.239$$
$$\mathit{Yellow}: \quad y_{densitometer} = -0.0043x_{dotmeter3}^2 + 1.2947x_{dotmeter3} + 11.319$$
$$\mathit{Black}: \quad y_{densitometer} = -0.0047x_{dotmeter3}^2 + 1.4000x_{dotmeter3} + 5.5886$$

	Residuals			
	Cyan	**Magenta**	**Yellow**	**Black**
Max	8.50	4.56	3.74	4.96
Average	1.89	2.19	1.88	1.79

Table 11. Dot meter 3, densitometer: Residuals in % when the test set is part of the training set. (Test set: "NR1 Trykk 24000", 1. measurement series.)

	Residuals			
	Cyan	**Magenta**	**Yellow**	**Black**
Max	8.94	6.31	10.02	6.17
Average	2.93	3.39	4.87	2.44

Table 12. Dot meter 3, densitometer: Residuals in % when the test set is different from the training set. (Test-set: "Orkla Trykk 5000".)

Conclusions and Perspectives

Our statistical analysis showed that due to large uncertainty of the estimated parameters, the model does not accurately describe the relation between the two measurement technologies. This can be explained by the poor repeatability performance for dot meters applied in newspaper print. The repeatability analysis provided, already in the first part of this study, low confidence using dot meters in newspaper print. None of the three dot meters fulfilled the requirement of 2% tolerance deviation (note: these are requirements which are not defined in an official standard). Dot meters are originally developed for measuring printing plates only.

The residuals between predicted and measured half tone values with the densitometer increased when the test set was different from the training set, as would be expected. Moreover, the measurement results have shown significant variations within the three dot meters. Some factors affecting the repeatability and determining the performance of the model are listed in this section.

Important factors that impair the use of dot meters on newspaper print:

- Print irregularities cause noticeable differences in measured halftone values and reduce the repeatability when the aperture is small.
- Small aperture in combination with large halftone dots used in newspapers are unfavourable.
- Due to high optical dot gain (especially for the middle tones and in newspaper print) it is ambiguous to decide what is substratum and what is part of a screen dot.

- Large residuals between predicted and measured halftone values for the middle tones could partly be explained by the high optical dot gain and problems due to determination of threshold (what is substratum and what is not) in the image analysis

Important factors that impair the use of densitometers on newspaper print (when using the Murray-Davies equation to calculate halftone values):
- The convertion from logarithmic density values into halftone values with the Murray-Davies equation causes a slowly decreasing graph that makes low density values converted to halftone values result in larger variations than high density values
- The effect of this conversion is even more obvious when used with low solid ink densities like in newspapers

Based on these results, dot meters are not recommended for halftone measurements on paper substrates in newspaper printing.

Throughout this project some ideas of further research to investigate a possibly relation between densitometric and planimetric measurement emerged.

The test target was printed in different printing processes with different solid ink densities, even though the instructions for printing said K 1.10 and CMY 0.9 in accordance with ISO 12647-3 (2005). It is difficult to control this in newspaper printing. It would have been interesting to do the same experiment with a print medium where accurate solid ink densities are possible. The uncertainty of dot meters and densitometers for use in newspaper printing is too high. Another type of paper (with lower optical gain) would also be preferable. To increase the repeatability it is advantageous with coated paper, accurate solid ink density and finer screen ruling (the aperture size would not be so critical). Moreover, FM-screening could be used. The reason why we did this experiment with newspaper in the first place is the increasing use of dot meters in the newspaper industry.

More than one copy of each instrument could have been included in the repeatability analysis to make any variations between copies become visible.

Image analysis of halftone images would be interesting to investigate the decision of threshold (what is part of a screen dot and what is not) and to illustrate the percent of optical dot gain for different halftone values. Different thresholds could be set and the result (dot area coverage) could be compared to measured values for the different dot meters. Different size of aperture could also be simulated to observe the influence of calculated dot area coverage. This experiment could perhaps lead to a recommandation of optimal size of aperture for different screen rulings; what size of aperture is necessary to avoid systematical errors?

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