CORRELATIONS BETWEEN FORMATION ANALYSIS PARAMETERS AND PRINT QUALITY IN COMPLEX IMAGES

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ABSTRACT

Print quality in images is a very important quality parameter for the evaluation of the printability. The paper is the material where the pigments and printing fluids are deposited and is one important factor in determination of the printability. The sheets ability to print sharp and well-defined halftone dots in a complex or natural image is not extensively studied.

This paper will focus on the relation between paper formation measured by both optical and beta formation analysers and the print quality in images from a prediction model. The statistical prediction model will be published fully later in a complete version and is at the moment confidential. That does not prevent publishing of the correlations between the model and the paper formation, which will be presented in this article.

The paper grades in this particular study were newsprint paper grades and ranges from mainly modern paper machines with gapformers. It is common to print both black and white and full colour images in newspapers.

Keywords: Formation analysis, Image analysis, Print quality assessment, Newsprint paper grades

INTRODUCTION

Image print quality is an interesting topic to study in relation to paper properties. Many of the parameters in the printing process override the paper properties, but the paper material is the basis for the pigments. The fundamental paper property is undoubtedly the paper formation.

Paper formation can be measured by principally two methods, which are optical and beta formation analysis. The most modern formation analysers acquire transmission images of the paper structure. These images can then be analysed by statistical, frequency or/and image analysis to characterise the structure of the paper formation and to extract parameters interesting for e.g. correlation with print quality.

Print quality for newsprint paper grades has been studied previously, and Bernie and Douglas [1] established a correlation between formation and print quality for North American newsprint paper grades, and concluded that the highest correlation between print ranking and formation nonuniformity was achieved in the scale range 4 – 8 mm with a correlation RSQ of 0.56. Bernie, Romanetti and Douglas [2] studied three years later paper formation with the aim to predict print quality, and by partition formation into scales of formation in the range of 0.6 – 37 mm concluded that the smallest scale of formation in the range gave the highest correlation RSQ of 0.60 with print quality of solid black sections of commercially printed newspapers. Kajanto [3] stated that it is important to know which mechanisms of formation that affect the print quality and concluded that formation is responsible for about 25% of the local print density variations or print unevenness for uncalandered papers. Poor formation or high local grammage variation implied a higher correlation with local print density variation. Calendering increased the effect of formation on print unevenness with correlation ranging up to 60%, and the hard and soft nip calandering had the same effect. Farell, Chen and Lauber [4] concluded that the process variables retention, fibre length and freeness controlled the paper properties formation, porosity and smoothness that again affected print quality parameters and runnability. The print quality parameters were print mottle, show through and halftone dot roundness. Trollsås [5] studied the print quality dependence on small-scale grammage variations of paper in letterpress printing with photopolymer plates and indirect lithography printing. The formation of paper expressed as grammage variations assessed by the variation coefficient was found to affect the small-scale transfer of ink to the sheet in printing and lead to small-scale print density and dot size variations. The conclusion was that the uneven small-scale distribution of the fibre material affected the small-scale transfer and distribution of ink.

Ness and Göttsching [6] studied the relationship between formation of paper and mottling in solid prints for uncoated woodfree offset paper, and concluded that there is a high correlation between the structure of an unprinted paper measured in transmitted light and the structure of ink distribution on paper measured in reflected light. The correlation coefficient R between the formation index and the mottling index was 0.63. Shallhorn and Heintze [7] concluded that there exists a relationship between the optical formation and uniformity of offset prints on uncoated woodfree fine papers with a correlation coefficient RSQ of 0.41. Kajanto [8] concluded that there exist a relation and a positive correlation between beta formation, explicitly given by the paper unevenness, and print unevenness for woodfree offset papers, especially in the range between 2.1 and 6.3 mm. The paper unevenness could be compensated and reduced by soft nip calendering.

Erho et.al. [9] described the Tapio Printatbility Sensor (TPS), an additional sensor on the Paper Machine Analyser (PMA), and its ability to estimate and report print quality parameters from a number of unprinted paper properties measured by a one-dimensional sensor analyzing the unprinted paper surface micro structure to determine the print quality potential, especially for rotogravure papers. Lyne and Jordan [10] studied the application of image analysis in print quality assessment, and discussed illumination of samples, image magnification, grey level gain, contrast, optical density, and measurement of solid prints and halftones, and concluded that these are all factors of importance in evaluation of print quality.

Print quality assessment of printed complex images by digitalization and image processing has not been intensively studied before. At PFI print quality in complex images has been studied during the last three years, and routines for aligning images, performing frequency analysis and development of print quality prediction models have been done.

The prediction model for newsprint paper print assessment will be used in this article to statistical correlate with formation parameters from the similar paper samples. The formation parameters range from very high resolution data to the more low resolution data. Both beta and optical formation is evaluated against the print quality predicition model. Regarding figure 1, the work in this article focuses on the formation part, from the formation image acquisition on the left side to the statistical correlation at the bottom, and the development of the statistical prediction model on the right side will be published separately at a later stage.

METHODS AND EXPERIMENTAL

Acquisition of formation images

The acquisition of the beta formation images was done using the Fujifilm FORMEX/BAS-1800 system. The system uses Imaging Plates (IP) to record the beta ray signal in the Fujifilm FORMEX unit. The Imaging Plates were then scanned in the Fuji BAS-1800 scanner. The pixel resolution was 50 µm. The image intensities were corrected according to the simultaneously recorded Mylar film weights with grammages equivalent to 50, 100, 150 and 200 g/m^2.

The acquisition of the optical images was done by using the high-resolution digital Eyelike camera. The spatial resolution was 50 µm. Background correction was used to eliminate for non-uniformities in the light source. The optical intensity levels of the individual samples agreed well with calibrated optical measurements done on the Tapio Formation analyser.

Analytical overview

The different analytical routines in this study are described in the flow diagram in figure 1. It is divided into three main parts of analysis, the spatial domain, which includes image acquisition, calibration and alignment, the frequency domain, which includes the two dimensional forward fast Fourier transform, analysis of the frequencies including identification of half tone dots, subdivision of the frequency space into more manageable subfrequencies, and the statistical analysis, that includes multivariate data analysis, model prediction and statistical correlations. As explained above only the left side of figure 1 will be discussed in detail.

Frequency analysis and parameter extraction of the formation images

It is reasonable to assume that the readers of this paper are familiar with the two dimensional fast Fourier transform. The frequency analysis of the formation images were done by subdividing the two dimensional Fourier space into more manageable subfrequency groups ranging from a resolution of 50 µm (=0.050mm) to 50 mm. The parameter extraction included these groups from both optical and beta formation images. Average spectral density was used as a formation parameter from each of these frequency groups.The different analytical routines in this study are described in

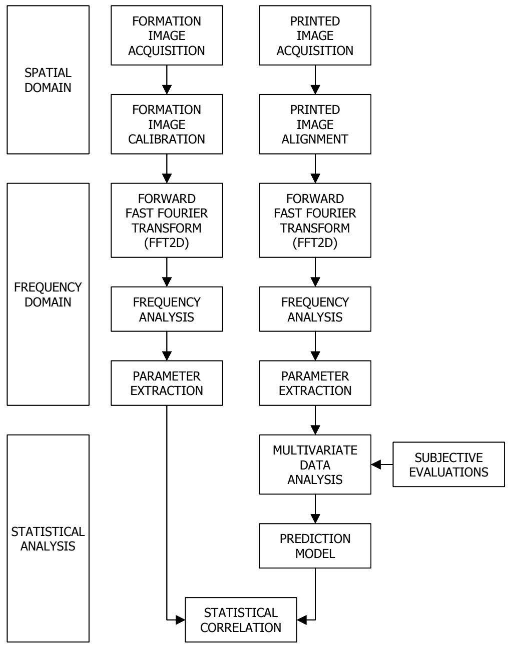
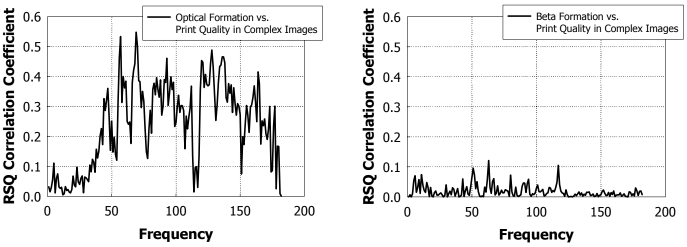


Figure 1. Analysis overview. The analysis is divided into the different parts, grouped into three different main groups of analysis: Spatial domain, frequency domain and statistical analysis. The first step in the analysis was to perform the image acquisition and calibration. The Fast Fourier Transform (FFT2D), frequency analysis and the parameter extraction were performed in the frequency domain. Statistical correlation with the print quality prediction model was performed under the statistical analysis part.

RESULTS AND DISCUSSION

Statistical correlation between optical and beta formation and print quality prediction model

The diagram in figure 2 represents the RSQ correlation coefficient values between optical and beta formation and the print quality prediction model for newsprint papers as a function of frequency. Figure 2 a) and b) shows that there exists a significantly difference between the optical and beta formation in order to explain print quality of complex images on newsprint paper. In special medium to high frequencies have large differences when optical and beta formation is compared. In figure 3 the data for the maximum peak where the correlation coefficient RSQ equals 0.55 in figure 2 a) is plotted.



a) b)

Figure 2. Statistical correlation between print quality in complex images and a) optical formation and b) beta formation as a function of frequency. Optical formation shows significantly higher correlation with print quality than beta formation.

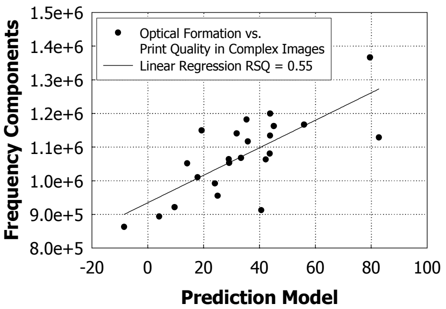
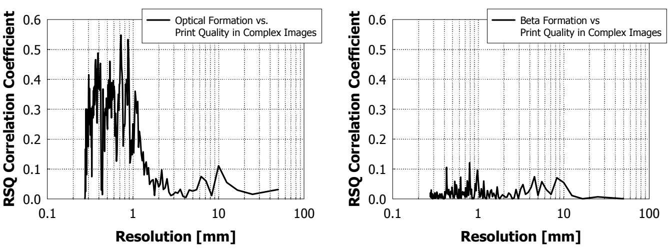


Figure 3. Linear regression for the statistical correlation between optical formation and print quality in complex images for the maximum RSQ correlation coefficient in figure 2a).



a) b)

Figure 4. Statistical correlation between print quality in complex images and a) optical formation and b) beta formation as a function of resolution scale in millimeter (mm) units. Optical formation shows significantly higher correlation with print quality in the resolution range from 0.2 to 2 mm compared with beta formation.

The curve in figure 4 a) can be divided into at least two different parts, one from the resolution of 0.2 – 2 mm and the next from 2 – 50 mm. The first part shows the relatively high correlation region and the last part the low correlation region when formation parameters and print quality in complex images are evaluated. Maximum correlation occurs when RSQ is equal to 0.55 and is given for a resolution of 0.725 mm.

In general the shape of the curve in figure 4 a) shows that the high resolution formation is the most important concerning the relationship to print quality in complex images. The differences between optical and beta formation can be explained by the importance of the optical properties. The optical properties through the structure of the sheet is important when optical formation is measured by optical transmission in the z-direction as well as the variation of optical formation in the x-y directions. The optical properties are also important when print quality is evaluated. Standardized reflecting light is used against the printed regions of the paper during the print quality assessment. The simultaneous variation of optical properties and print quality parameters in the x-y directions seems to be an very important factor and reason for the relatively high correlations between optical formation measurement and the print quality prediction model.

The prediction model is primarily based on the definition of the raster points, and the frequencies around the raster points in the Fourier domain. The raster point consist of a sharp periodic frequency from the periodic distance between the raster points and a higher frequency from the definition of the raster point edges. It seems reasonable to believe that a covariation between the frequencies in the optical formation and the frequencies in the definition of the rasterpoints gives the optimal or best correlation.

CONCLUSIONS AND FINAL REMARKS

Optical formation measurement detects and indicates better the papers print quality potential of complex images for newsprint paper grades than compared to beta formation measurement.

The high frequency part of the formation, equivalent to the resolution below 2 mm, based on the optical formation images correlates better with the print quality prediction model for complex images for the coldset web offset (CSWO) print trails for the newsprint paper grades samples.

To improve the papers print quality potential of newsprint paper grade samples one should focus on the high-resolution region below 2 mm, the sub 2 mm range of the formation. This region explains best the differences between the print quality variations in the complex images.

FURTHER WORK

Further work will be to map the relation between formation analysis parameters and print quality in complex images on other paper grades and printing methods. Methods may also be developed to treat four-colour prints.

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