Comparison of Image Analysis Tools for the Evaluation of Paper Topography and Print Characteristics

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Keywords: Topography, roughness, image analysis, digital print, offset print

Abstract

This research in regards to paper topography and roughness and their influence on print quality is a continuation of the research presented at the 2010 conference in San Diego. For that research comparisons were made in regards to the print quality between offset and digitally (toner-based) printed products. The comparison was made between coated and uncoated stocks. This research expanded the comparison to the stocks with matte surface finishing. It was found that there was a direct correlation between the topography of the tested papers and the resulting circularity of the printed dots for offset printed products. For digitally printed products the roughness value of the tested papers correlated better with the resulting dot circularity. The evaluation of the printed samples took place with the use of high-end precision flatbed scanner and computer based image analysis software called Verity IA.

During the previous project open-source software called ImageJ was also tested for the evaluation of the tested papers. The functionality of the open source software can be extended through plug-ins. An initial correlation between the roughness values of both software solutions was found, but further analysis is required, since some of the tested papers did not give consistent results with both applications. It will also be tested how other plug-ins can be used for obtaining better results and also give the open source software, to a degree, similar functionality like the commercially available software. The scope of the previous research paper will be extended to include additional coated and uncoated papers that will be tested on an offset and a digital printing press.

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Toners used in digital print technologies are more opaque then lithographic inks, which are mostly transparent. This poses a unique challenge for the image based analysis software, since the software was initially developed for the evaluation of offset printed products. Optical print density will be evaluated for offset and digitally printed test forms and the results will be compared conventionally obtained print density values through the use of a densitometer. It will also be tested if both software solutions can be used to determine the printed density through image analysis.

The circularity plug-ins for ImageJ gave very similar results for all the tested papers, independent of the amount of printed dots included in the sample area and any image enhancement that has been done prior to the analysis.

A 3D-plugin for ImageJ created a 3D-map of the tested papers, which in turn illustrated nicely the obtained topography and roughness evaluations done through the Verity IA software.

Our conclusion is, that the Verity IA software is more versatile and fine-tuned than the ImageJ software, which has been enhanced in its functionality through plug-ins for this study and can be considered an additional tool to the commercially available software solution.

The correlation in regards to the roughness evaluation of a tested paper still exists between both software solutions.

Introduction

The topography (microscopic analysis) of the paper surface has a great influence on the final printed result. This paper evaluates the influence of the paper topography on the quality of the printed dot reproduction and therefore the overall print quality in offset and digital printing. Earlier works done by Rosenberger (Rosenberger 2003, Rosenberger 2006) analyzed paper topography in relation to gloss mottle and print mottle. Other researchers have used white-light interferometry (Sprycha et al., 2006) to determine the surface characteristics of paper using interference fringes of visible light.

The topic of studying the topography of paper surfaces in relation to printability is not a new topic. The approach taken in this research paper is of a different kind of nature and involves the study of print properties of the same papers used for sheetfed offset print technology and for digital toner-based print technology. A study done by Du (Du, 2008) determined the surface characteristics of the studied papers through topography, structure and surface tension. Du states that it is important that the method used for paper topography measurement does not apply pressure to the paper specimen, since it can influence the result.

Dickson and Chinga (Dickson and Chinga, 2008) investigated the influence of a certain fibrous raw material on the paper quality and the resulting print quality. They tried to find a relation between ink coverage and variations in sheet grammage and topography and found that grammage variability had a greater influence on ink coverage than did the topography variability.

Loffler, Dusting and Vanderhoek looked at the relationship between ink jet print quality and paper formation and roughness (Loffler et al., 2007). Their investigation varied the type of inkjet printer as well as the type of uncoated fine paper. The combination of inkjet printer and one of the eleven uncoated papers were tested for colour density, gamut, mottle, grain, dot gain, line width and inter-colour bleed. Correlation between some of the individual print parameters has been found and some dependence of the print result on the paper surface and formation.

In 2003 Sirvö conducted a study on paper properties for modern dry toner presses (Sirviö, 2003). His study emphasizes that surface evenness and good uniformity is more important to print quality than electrical properties on the macroscale.

Hannsson and Johannsson (Hannson and Johannsson, 2000) describe in their article stereophotometric method to study reflectance and topography at the same time.

From this literature review it can be seen that many different attempts have been made to assess the topography of the surface that will be printed on and relate it to the achievable print quality.

Experimental

In this study test charts were printed on a PrintMaster PM74 press and a Xerox DocuColor 7000 digital press. All images for the analysis by both software solutions were captured with a high-end scanner, which is part of the Verity IA package. This was done to capture a higher amount of printed dots, so more meaningful statistical data would be acquired. The Verity IA software uses algorithms that are based on stochastic frequency distribution analysis (SFDA). This analysis method was described in our previous research paper (Habekost et al, 2010).

The only difference between our previous research paper and this study is, that the chosen dot shape for the offset press was round and not round-elliptical.

Additional plug-ins used for the ImageJ software were “Interactive 3D surface plot” by Barthel (Barthel, 2011) and “Circularity” by Rasband (Rasband, 2011).

The following papers were tested:

Paper	Basis weight	Grammage
Matte 1	100 lb	148 g/m^2
Opaque 1	80 lb	119 g/m^2
Gloss 1	100 lb	148 g/m^2
Gloss 2	100 lb	148 g/m^2
Opaque 2	80 lb	119 g/m^2
Gloss 3	100 lb	148 g/m^2
Matte 2	100 lb	148 g/m^2
Matte 3	100 lb	148 g/m^2

Table 1. List of tested papers.

Results

Results from the 3D surface Plot

Blank strips of the tested papers were scanned in and used for the 3D plot. In total there were eight papers tested. There were three matte papers, one paper with the classification “smooth” and three gloss papers. Alone from this one would expect the coated papers to have a slightly smoother surface than the “smooth” papers and the matte papers should show the most structure, since a paper is matte, because it bounces the light in all directions.
Below are the images of all the tested papers.

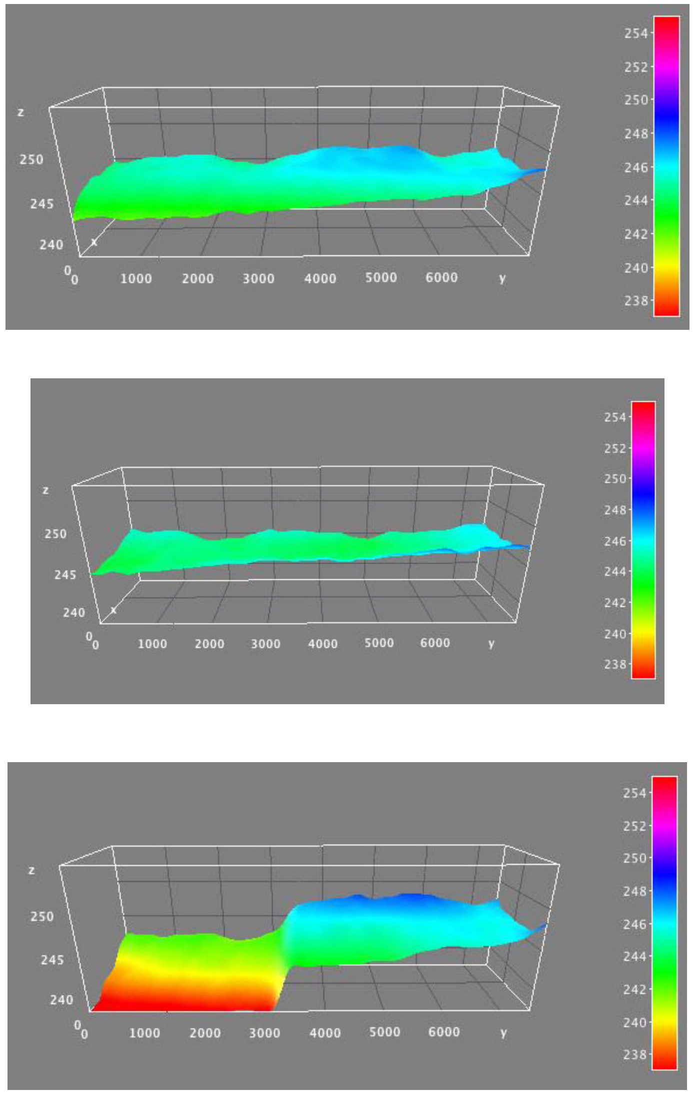


Figure 1. 3D surface plots of the three gloss-coated papers.

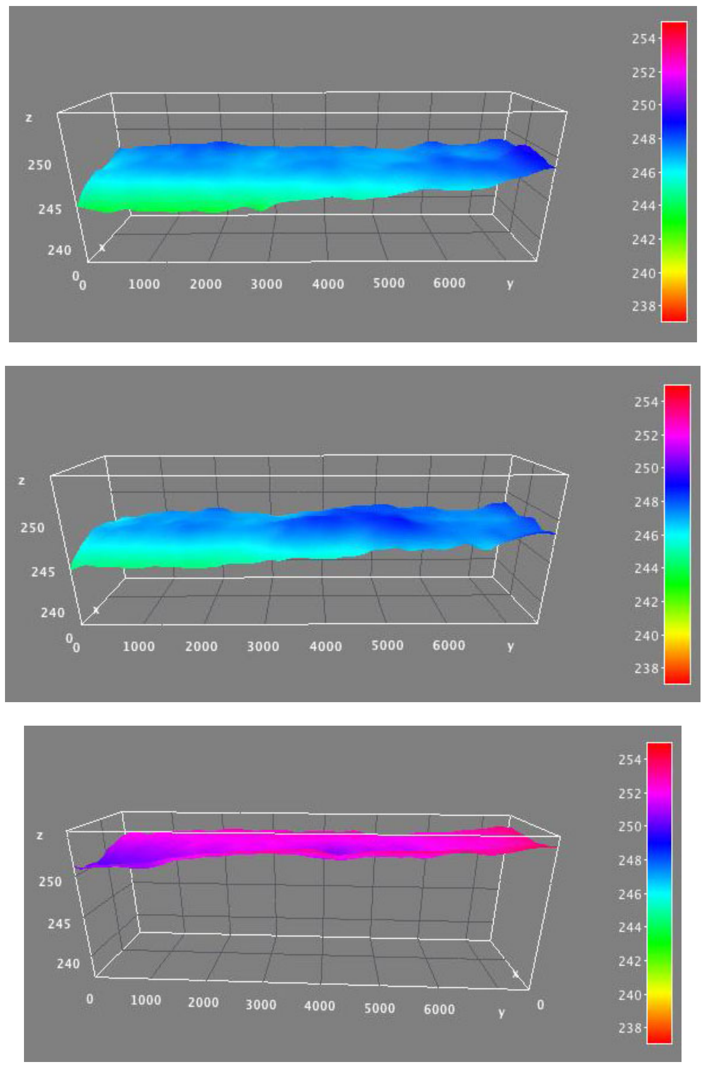


Figure 2. 3D surface plots of the three matte papers.

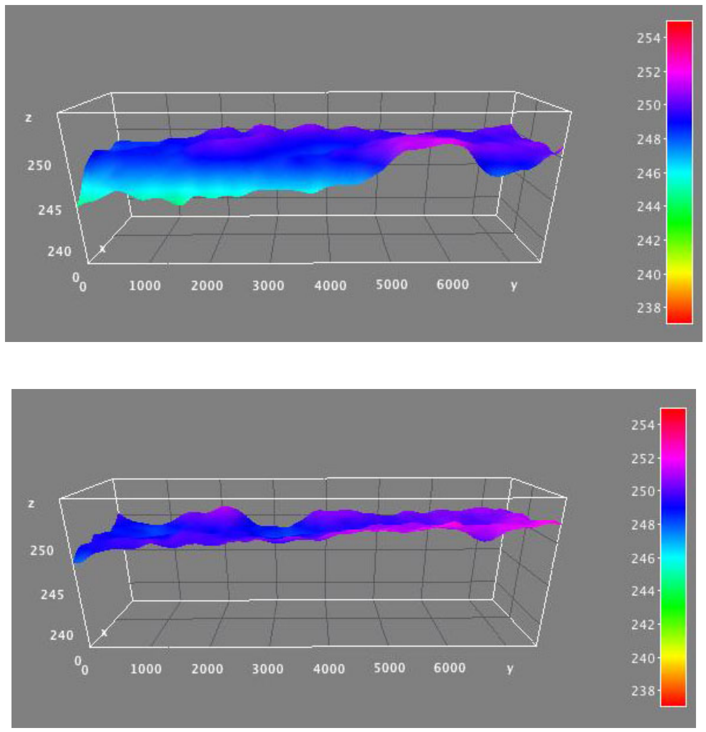


Figure 3: 3D surface plot of the two smooth papers.

From these 3D surface plots it can be seen that the paper classified as "smooth" has the roughest surface. Even the matte papers show a relatively smooth surface, so it will be interesting to see what the results for topography and roughness of these papers will be.

Roughness Results for the Tested Papers for Both Software Ppackages

For determination of the roughness values the test papers were scanned at 1200 ppi and the area of interest was 626 mm^2. A visual presentation of the measurement values can be seen in figure 4.

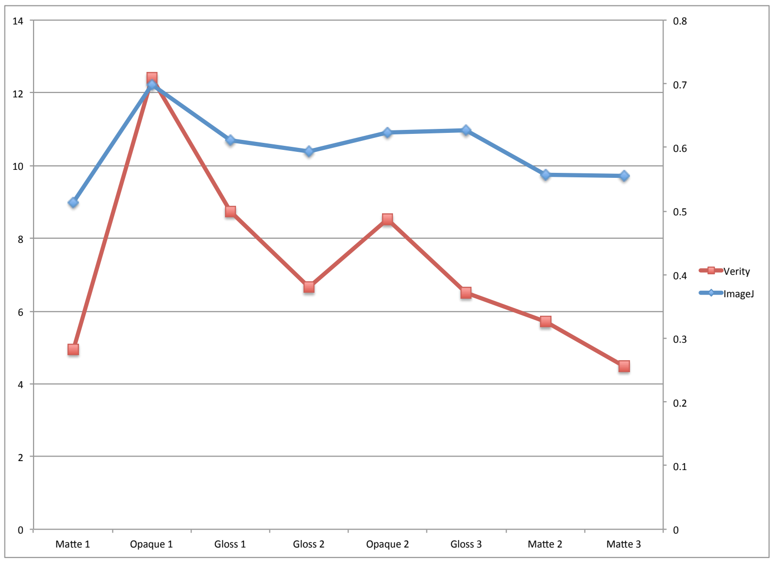


Figure 4. Comparison of roughness values between the tested software packages.

The measurement values from figure 4 are listed in table 2.

Paper	ImageJ	Verity
Matte 1	0.514	4.94
Opaque 1	0.698	12.42
Gloss 1	0.611	8.73
Gloss 2	0.594	6.67
Opaque 2	0.623	8.53
Gloss 3	0.627	6.52
Matte 2	0.557	5.71
Matte 3	0.555	4.48

Table 2. Comparison of roughness values obtained from both software solutions.

From figure 4 it can be seen that there is a correlation between the roughness values from both software solutions. In the following figure the roughness values from both software solutions were plotted against each other.

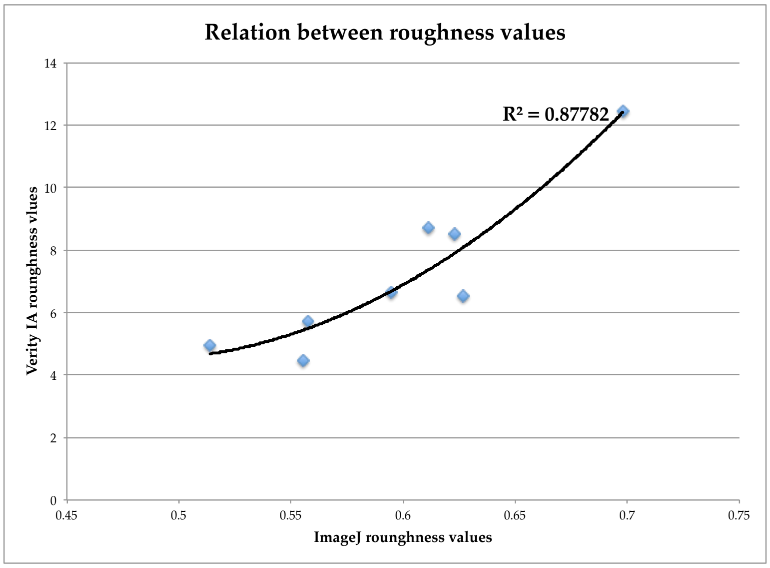


Figure 5. Comparison of roughness values obtained from both software solutions.

As it was shown in the previous research paper (Habekost et al., 2010) there is a correlation between the roughness values from both software solutions. A similar r^2-value was obtained. In the 2010 research paper the r2-value was 0.853, so this year a slightly better correlation was found, but it is not a 1:1 translation of roughness values. As stated previously (Habekost et al, 2010) the roughness plug-in for ImageJ can be used to determine the roughness values of paper surfaces.

Circularity Measurements with Both Software Solutions

The functionality of ImageJ software was increased by installing the circularity plug-in developed by Rasband (Rasband, 2011). Circularity measurements done with this plug-in gave the same circularity results independent of the paper that was analyzed on the screen percentage that was analyzed. Therefore this plug-in did not prove useful for any circularity analysis of printed halftone screens.

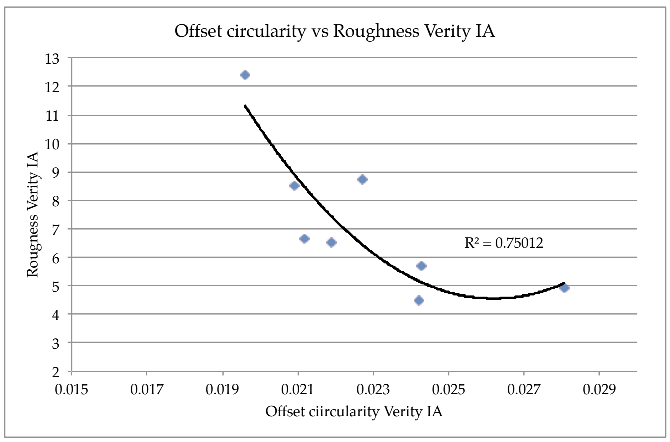
Circularity Measurements in Relation to Topography and Roughness Measurements

Since circularity measurements were only possible with the Verity IA software any correlation between these measurements and the topography and roughness values of the tested papers were sought. Topography measurements were only possible with the Verity software, while roughness measurements were possible with both software packages. The results from these comparisons can be seen in the table 3.

Property	Offset circularity	Xerox circularity
Topography Verity	0.814	0.384
Roughness Verity	0.750	0.240
Roughness ImageJ	0.829	0.050

Table 3. Correlation values (r^2) between circularity measurements and topography and roughness measurements.

Table 3 shows clearly that there is a good correlation between the circularity measurements of the offset printed samples, whilst there is no correlation between the circularity measurements of the digitally printed samples. The correlation between roughness and circularity can also be seen in figure 6.



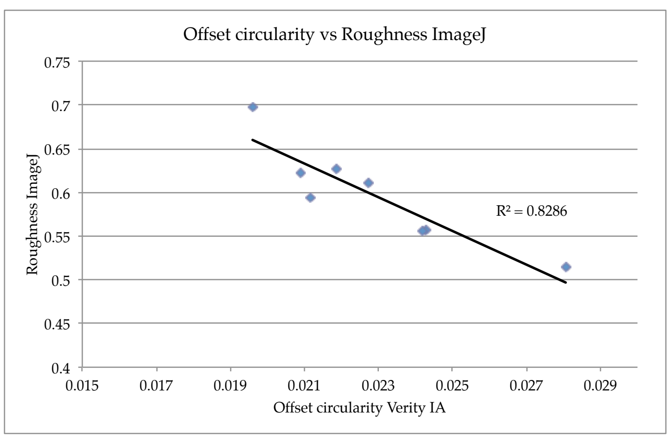


Figure 6. Correlation between offset circularity measurements and roughness values obtained through the tested software applications.

Halftone Mottle and Visible Print Mottle

Print mottle can be caused by an uneven paper surface, water interference, back-trapping and ink trapping. The mottle caused by the paper surface is in relation to non-uniform absorption properties, non-uniform base sheet contributing to gloss variations. Print mottle can also be caused by an optical incompatibility between the base-sheet and the coating.

The visible print mottle is the mottle of a solid print ink surface, while the half-tone mottle, as the name indicates, is a non-uniformity within the printed half-tone dots.

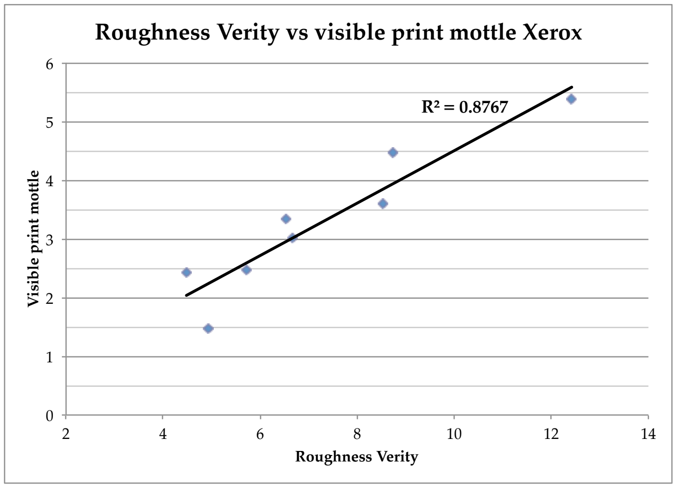
It was attempted to find a possible correlation between the topography and roughness measurements of the tested papers and the visible print mottle. The mottle measurements were done at 1200 ppi and the area of interest was 626 mm^2 and the measurements were don on a 30% tint of cyan. It was not possible to measure halftone mottle for the digitally printed samples. This is probably due to the fact that there is no halftone mottle within the digitally printed dots.

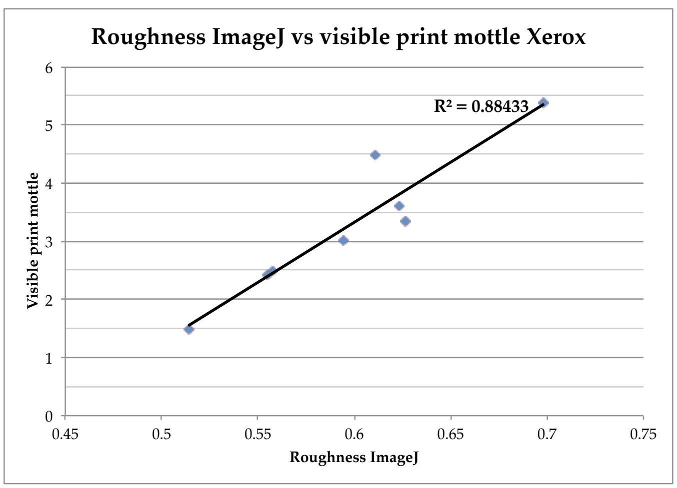
The measurement data can be seen in table 3.

Paper	Roughness Verity	Topography Verity	Roughness ImageJ	Visible print mottle offset	Halftone mottle offset	Visible print mottle
Matte 1	4.94	1.71	0.5143	1	10.225	1.47
Smooth 1	12.42	58.3	0.6979	1.3	10.425	5.38
Gloss 1	8.73	10.46	0.61104	1.1675	11.6625	4.48
Gloss 2	6.67	7.16	0.59442	0.576	5.5325	3.02
Smooth 2	8.53	18.27	0.62312	1.3875	12.2125	3.6
Gloss 3	6.52	11.98	0.62664	0.78125	7.3565	3.34
Matte 2	5.71	4.66	0.5574	0.615	5.8625	2.48
Matte 3	4.48	2.24	0.5551	0.8325	7.3375	2.43

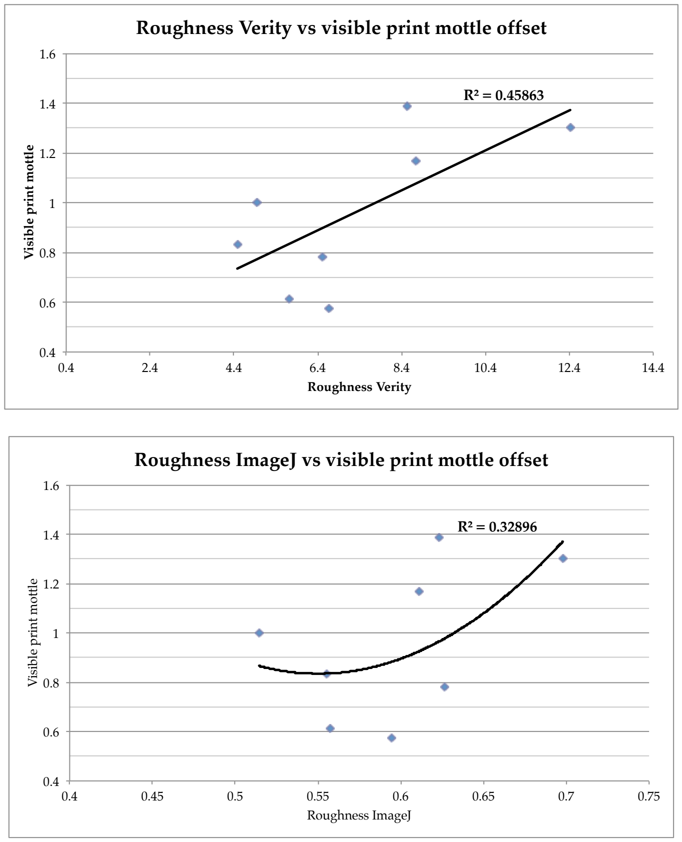
Table 3. Visible print mottle and halftone mottle, roughness and topography values of the tested papers.

A visualization of these measurement values can be seen in figures 7 to 12.

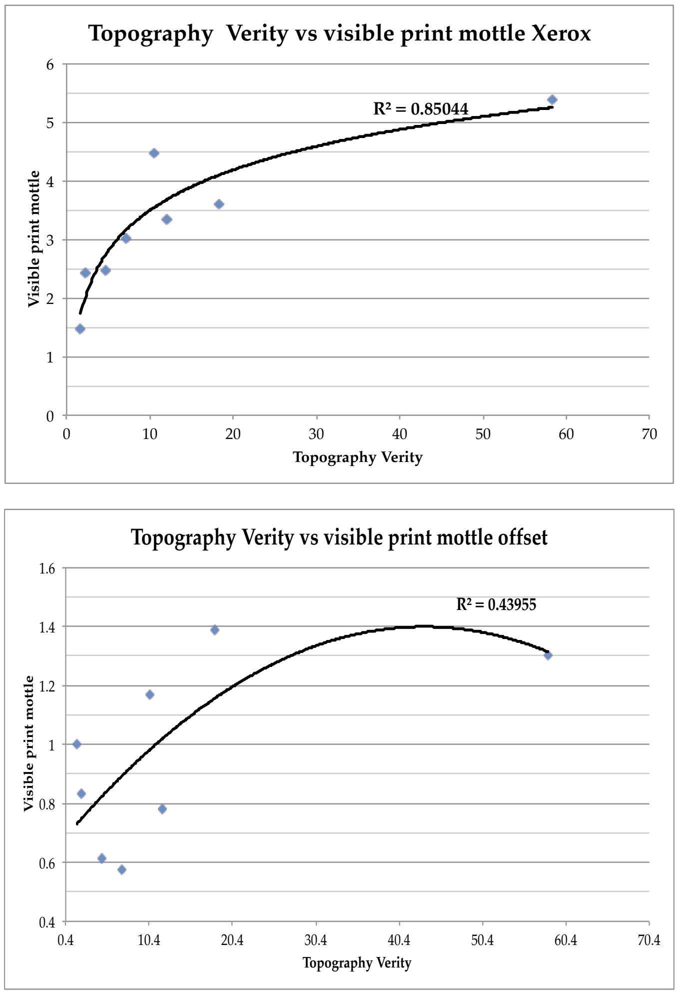




Figures 7 and 8. Visible print mottle Xerox against roughness measurements for both software solutions.



Figures 9 and 10. Visible print mottle offset against roughness measurements for both software solutions.



Figures 11 and 12. Visible print mottle against topography measurements.

From the figures 7 to 12 it can be seen that there is a good correlation between the topography and roughness measurements and the visible and half tone mottle for the digitally printed samples. It was interesting to see that the roughness measurements from both software solutions correlated well with the visible print mottle. There is also a good correlation between the topography measurements and the visible print mottle measurements for the samples printed on the digital press. This correlation does not exist for the offset printed samples.

Conventional Quality Assessment of the Printed Sheets

A more traditional way of judging the print quality was also the assessment of the mid-tone tone value increase for the printed samples. Guidelines for the tone value increases were compared against published recommendations from PIA (PIA, 2007). Like in the previous research paper (Habekost et al., 2010) the tone value increases for the digital press were above the recommended 20 to 22% for cyan and more in the 25 to 32% range, but the same can also be said for the sample that were printed on the offset press. Although a higher tone value increase was recorded for the offset printed samples, they were the same as the digitally printed ones. This means that the analyzed samples had similar print characteristics, which made the samples also more comparable to each other.

Conclusions

The main result of this study was, that the open-source software ImageJ could currently not compete with the commercially available image analysis software from Verity. The 3D plug-in for ImageJ is nice visualization tool to show the structure of the paper surface, so it is easier to understand the influence of the paper structure onto the printed dot. In comparison to the previous study all images were captured using the high-end flat-bed scanner which is part of the Verity IA software solution. This increased the area of interest to about 1 square inch or approximately 650 mm^2. The number of dots analyzed therefore increased from 600 during last years study to about 9000, make the obtained data based on a larger sample size.

The roughness plugin for ImageJ used in this study has a good correlation to the roughness values obtained through the Verity software. This was repeatedly shown throughout this research project.

The circularity measurement plugin for ImageJ gave the same circularity values for all the tested papers and also independent from the print process that was used.

The circularity measurements done with the Verity software show a good correlation with the topography and roughness measurements from either software solution.

There is a good correlation between the visible print mottle and the roughness measurements from both software packages for prints made on the digital press used for this study. This correlation is not that present for the offset printed samples.

The print quality of the samples was also evaluated using tone value increase guidelines. Although the tone value increases from both print processes were higher than they should be, the printed samples showed the same amount of tone value increase, therefore making them more comparable.

Acknowledgments

We would like to thank print technician Peter Roehrig for conducting the press runs.

We are grateful to the School of Graphic Communications Management and the Faculty of Communications & Design at Ryerson University with their support & travel grant to enable this research and travel to the 63rd Annual Technical Conference of TAGA in Pittsburgh, PA in March 2011.

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