The Characterization of Gloss from detailed Semi Goniometric Measurements

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Abstract

Gloss has a profound impact on the quality of printed matter. The manufacturing of the substrate and the printing process result in varying amount of gloss from the print. A glossy print with a smooth surface give a high degree of reflection in a relatively narrow specular sector. This contributes to the observed density range and is usually regarded as beneficial from a qualitative perspective. On surfaces that are less smooth, such as newsprint, the print quality is very dependent on the way gloss is angularly distributed. From the measurements it is clearly seen that gloss can be observed at different scales. The fibers themselves as well as the filler and surface material reflect with different characteristics.

This paper is based on 360 degree angular measurements with a geometry of 60 degree illumination and zero degree detector. The specimen is placed in the instrument on a moving stage. Mechanically moving the specimen relative to the light source and digitally restoring the geometry create an impression of a moving light-source. In this paper we will focus on the gloss measured on a very detailed level (micrometers) as points of high reflection.

Introduction

Paper is a turbid media and as such it is scattering the light that enters the substrate. Some of the light is reflected already at the surface however. Depending the properties of the surface some of the light is reflected back specularly. The fraction of the light that is reflected this way is under some circumstances detrimental to the reproduction quality. This can very often be seen especially on rough surfaces. The angular distribution of the specular reflection is very important and determines the effect it has on the print quality. With a wide distribution it is not possible to create a large dynamic range. However, with a smooth uniform surface having highly oriented gloss the quality in terms of dynamic range is improved. Previous work has shown the importance of gloss in the contest of perceived and technical quality. Saarelma and Oittinen (1991) and Oittinen (1991) have discussed the aspects of how to define and measure technical print quality with focus on gloss. Arney (1993) has studied a gloss related problem of how to acquire the surface topography from a substrate. Extending the models regarding print on paper have also been done by Kruse and Wedin (1995) and Arney and Engeldrum (1995a,b). 3D modeling of light diffusion in paper was also simulated by Gustavsson et all (1995) However, the models do not take gloss effect into account. Neither in Gustavsson (1997) dissertation is gloss taken into account in the modeling.

Béland et al (2000) have shown that gloss variation relates well to quality, as does the width of the light scattering distribution. Ferwerda (2001) proposed a model for gloss perception. Lindstrand (2005) presents an apparatus for measuring gloss on a curved rotating surface.

Nyström and Kruse (2005) has studied high resolution prints on paper with focus on the halftone prints. Nyström (2009) describes the instrumentation developed at Linköping University for the purpose of detailed multispectral analysis.

The present paper is motivated by the lack of knowledge regarding paper surface gloss in different in-plane orientations. The anisotropy with regard to the incident light and observation is little known despite the inclusion in some standards ISO 8254-1, D 1223 and D 523.

Experimental System

In order to describe the experiment it is necessary to give a brief description of the instrument that has been used.

There are few instruments that can capture the full characteristic of paper with regard to the illuminating angle, the observation angle and the orientation around a perpendicular axis to the surface. The Oden instrument, Nyström(2005) which is a research instrument is very well suited to the required kind of measurements. It is a very well calibrated instrument unfortunately so far not commercially available.

Very briefly the Oden instrument consists of a high-resolution B/W camera attached to a motor controlled vertical screw by which the focus can be adapted to the sample height. The sample is attached to a moving stage that is motor controlled as well. The stage has three free axis of movement, up and down in the plane of optical focus and also rotationally around the optical axis.

The illumination source is a xenon lamp. Its light is guided through an optical fiber that can be inclined to the substrate surface by a moving motor controlled arm. The camera is always in the vertical position above the sample. On its way to the sample the light passes one of a set of 20 different selectable filters that are motor controlled. Through a special mechanical arrangement the light can also be made to reach the sample from below. In this case the camera instead of the normal reflection image captures a transmission image.

Through the optical arrangement resolutions down to 1.5 micrometer per pixel is readily obtained. This high resolution makes the field of view approximately one mm square. With other optical lenses this can be changed to a desired magnification. To conclude the brief description the entire instrument is under software control. Focus, position, rotation, choice of optical filter and illumination can all be changed by software.

To-day (spring 2009) several sets of measurements have been collected. The original set was a simple newsprint paper, however. This article is based on these early measurements.

Measurements

The measurements were carried out using the control program for the Oden instrument. The program has a convenient way of setting up an experiment so that the captured images are given file names on disk that show the given experiment name and the order in which it was captured. The original intention was to capture one set of 360 images, one image per degree of revolution. The inclination of illumination was selected to 60 degrees and the resolution to 1.5 micrometers.

In a setup like the Oden instrument there are of course always some restrictions in the way of selecting the parameters for acquisition. One such problem is the 360-degree of revolution. Had the geometry of the instrument allowed for a complete rotation of the illumination there would be fewer problems. However, due to construction this was not viable so in the experiment the specimen is forced to rotate instead. The consequences are that the captured images are rotated along with the specimen. Since the data is to be analyzed together we need a common co-ordinate system. Therefore the images have to be rotationally reset to the original orientation by digital processing. Had it not been for the mechanical imprecision this would have been a trivial thing to do. However the precision of sub micrometer positioning is not easy to accomplish. To achieve this by computation is less costly. Therefore for each position there are two images captured one reflection image and one transmission image. Since the transmission images do not change very much due to rotation they are excellent to use in a correlation scheme for finding the common center of rotation as well as the rotation angle by digital image processing.

In Figure 1 below are shown two images from the same position of the sample. The only difference between the two images is the orientation of illumination.

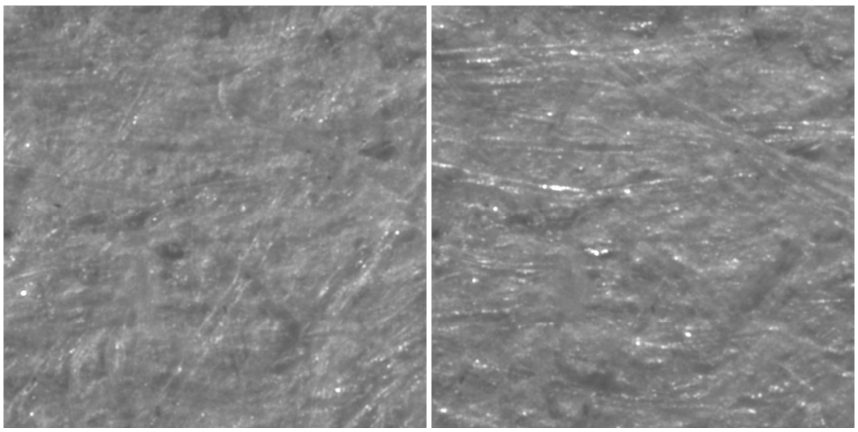

Figure 1. The same patch of newsprint illuminated from different angles. The illumination is 90 degrees apart in the plane of the paper surface.

Analysis

The digital preprocessing of the data resulted in a set of geometrically and optically well calibrated images each captured with illumination from one of the 360 orientations for a full revolution. After the preprocessing the trans-mission images did not take further part in the analysis.

The gloss analysis that we set out to do was intended to show the characteristics of gloss during rotation of the surface. Just by watching the sequence of images as a video on the computer screen revealed the different types of gloss that are present. This is of course highly dependant on the substrate composition. In our case of newsprint it was easy to spot fibers as well as small facets. The size of these was very different. The small gloss spots were only a few micrometers in diameter whereas the fibers were several tens of micrometers in length.

The analysis program supplied areas of high gloss in the set of images. A subset of these was selected for further analysis - the selection criteria being size and regular shape. Each of the selected gloss areas was for convenience sake also normalized with respect to orientation of the peak reflection. The locations in the reflection images of the selected areas were each converted into a sequence of reflection values over the 360 rotation range.

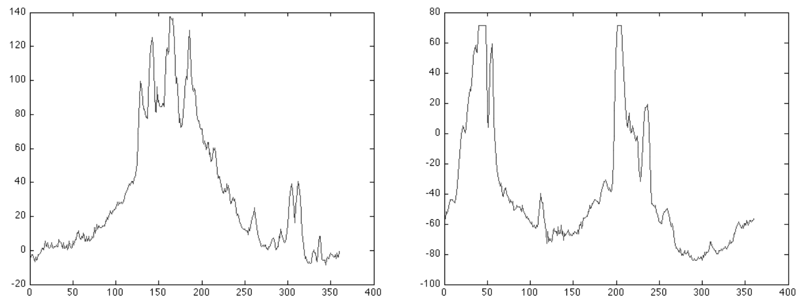

Figure 2. The dominating first (left) and second (right) harmonic averages after normalization. For the second harmonic the average signal is also subtracted. The vertical scale shows relative values and the horizontal shows the orientation in number of degrees.

The reduction of the captured data resulted in a set of sequences of reflection as function of rotation, one sequence for each of the selected gloss areas. Finally the data was subjected to a harmonic analysis and the results were classified with respect to the two first harmonics. Figure 2 shows average gloss areas with dominating first and second harmonic respectively. The response from the samples is difficult to normalize. Therefore there are several peaks in the diagrams above. In the right hand side figure there is also some clipping of the signal present. This is due to the image capture and would not be there had the range of the camera A/D-converter been wide enough. To circumvent this several exposures with different exposure times can be used in order to create HDR response. In the present series of measurements this was not done however.

Conclusions

The results from the analysis of the harmonics show that there are two main classes of gloss areas. One class has a dominating second harmonic. This corresponds to peaks in gloss twice per revolution. A close look at these areas showed that in the majority of cases the reflection originated from fibers. This may not be surprising since the visible cylindrical shape of the fibers probably will reflect light in orientations 180 degrees apart. Another cause for this is wire marks in the MD direction.

The class with high first harmonic was not as evident as the one with the second harmonic. These gloss areas were probably the result of reflection from micro facets with mirror like properties. It could be seen from the image data that they were quite small and not at all as large as the areas of the other class.

The conclusion of this paper is not only that big differences exist in the causes for gloss but also that the analysis of the presented kind can discriminate between the classes. A further analysis will give a deeper understanding of gloss and its causes. But that is beyond the scope of the present paper.

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