Glossmark™ Technology: Digital Printing Beyond Color

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Abstract

Glossmark™ image is a high contrast optical variable differential gloss image. Glossmark™ technology is the printing process that enables the simultaneous creation of high quality color graphics and striking Glossmark™ images in a single printing step. Its digital implementation has been demonstrated with electrostatic printing without the need of a special paper or toner. Glossmark™ technology utilizes the angular dependence of image gloss to create a differential-gloss image through the modulation of halftone structures. Both the primary and the embedded Glossmark™ image can be distinctively viewed from different perspectives with little interference. With its optical variable appearance, the Glossmark™ image breaks the limitation of current color reproduction systems. It naturally enables a print to reproduce/simulate the look and feel of many objects whose appearances strongly depend on the illumination and observation directions. The highly decorative visual effect of Glossmark™ images can be used to add significant appeal to an ordinary document. This implies better attentions to marketing materials, which in return would attract and more audiences. Creative combination of the primary images and the embedded Glossmark™ images can make a print quite entertaining. New applications and market segments can emerge from this new capability. Well-designed quality Glossmark™ images are also very difficult to copy making it ideal for document authentication.

Introduction

Gloss is a simple quantitative measure of the specular reflectivity of a surface. The gloss appearance of an object is a result of the interaction between the light source and the surface structure of the object. The gloss of a print is not only affected by the substrate, but also by the ink/toner and the printing processes used to create the print. When the substrate dominates the surface roughness, we have substrate dependent gloss which is generally uniform within a print. Examples of printing technologies in this category include traditional printing presses such as offset, gravure printing and flexography. Other printing technologies, such as xerography, produce prints that the ink/toner dominates the image roughness. Thus, the gloss of the prints created with these technologies are strongly image content dependent. As an uncontrolled by-product of printing, this image dependent gloss can result in a phenomenon known as differential gloss, which can be very objectionable to the observers under certain circumstances. Compare to offset printing, high end xerographic color printers have been able to approach the offset quality in terms of color, but most of them still suffer severely from differential gloss image defects. Within the xerographic printing industry, significant R&D investments have been directed towards the goal of reaching true "offset-like" uniform image gloss by suppressing the differential gloss of the xerographic prints.

On the other hand, differential gloss itself is not inherently undesirable under all circumstances. Some customers do prefer strong gloss contrast for certain images and applications. Therefore, gloss control, especially, image-wise gloss control should be the ultimate goal if it is technologically and economically feasible.

Traditionally, gloss control in xerography is achieved by toner design and fusing parameter variations. It is also typically assumed that the gloss of halftones at various area coverages is just a linear interpolation of the substrate and image gloss weighted by the area coverage. Under this assumption, the gloss of a halftone patch depends on only the image density and the intrinsic toner gloss (gloss of solid area). Therefore, there is little appreciation for the fact that the gloss can also be affected by the halftone structures. In this paper, we will first discuss the phenomena of halftone orientation dependent image gloss. Then we will demonstrate embedding a differential gloss image within a high quality color image by exploiting the relationship between the image gloss and halftone orientations.

Anisotropic Surface Roughness and Orientation Dependent Gloss

As we know, gloss is driven by the surface structures and under most conditions, these surface structures are isotropic. A mirror is equally reflective regardless of the azimuth of the light source relative to the plane of the mirror. Similarly, an ordinary blank paper is equally reflective regardless of the azimuth of the light source. There is no preferred alignment or elongation of the structures averaged over a macroscopic length scales. Thus it is sufficient to use gloss to specify the image surface property without referencing the measurement orientation with respect to the image.

Printing is a process that certain marking materials (toner or ink) are deposited onto the substrates to create density /color variations. In most of these processes, the ink/toner materials are deposited in a patterned fashion other than uniform solid or contone. These patterns known as halftone structures are sometimes very anisotropic. For example, line screens and elliptical dot screens are both having strong preferences for dot/cluster orientations. Although these halftone patterns are intended only to achieve certain planar density variations, they inevitable influenced the surface roughness indirectly through the ink/toner deposition processes. Hence, anisotropic halftone structure will likely to introduce anisotropic surface roughness and anisotropic gloss response. As we will learn later that printed matter can and will often display differing reflective characteristics depending upon the structural orientation of the halftone. Therefore, it is important to examine the gloss responses of halftoned images with respect to the relative direction between the halftone structures and the measurement directions.

Figure 1 illustrates the typical geometries for gloss measurements. The image surface reflects the incident light AO in all directions and its specular response is measured by the amount of light reflected into a small aperature in the directions around OB, the direction of its mirror reflection. The incident angle of the light θ for gloss measurement is chosen according to the applications and the smoothness of the surface. Both $\theta = 75^o$ and 60^o are among the standard choices for both images and substrates gloss measurement within the printing industry. For isotropic surfaces, the incident angle is sufficient to define the measurement. A second angle β is required to specify the geometry for anisotropic surfaces as shown in the figure. Direction OH can be of arbitrary choice within the surface and here it is set to the elongation direction of the halftone clusters/lines for convenience. Β is the angle between OH and OB', the projection of the specular reflection OB onto the measurement surface.

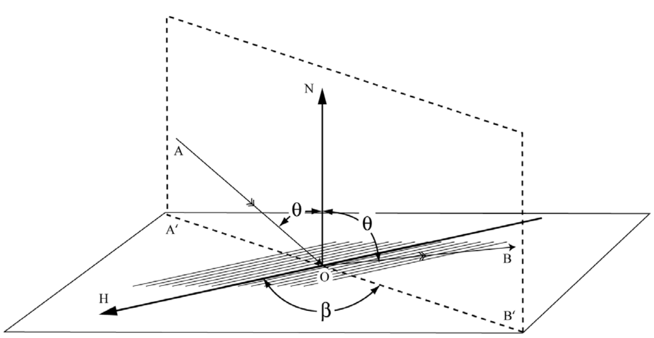

Figure 1. Gloss Measurement Geometry of Anisotropic Surfaces

Figures 2 show some gloss measurements of a printed sample according to the geometry illustrated in Fig. 1. The sample is an electrostatic print with 200lpi line screen on Lustro Gloss paper. The gloss variation of a midtone (60%) patch against angle β is plotted in Fig. 2 (a) with β within a range of 0^o to 90^o. By symmetry, the gloss responses outside the specified range of values of β can be simply mapped to the values plotted on the figure. As expected, big variations in gloss exist with the gloss contrast maximized between parallel ($\beta=0^o$) and perpendicular ($\beta=90^o$) configurations. Although the contrast is very significant, there has little appreciation of this phenomenon from ordinary viewers since the difference in gloss has to be viewed under different illumination conditions before the visual memory is lost.

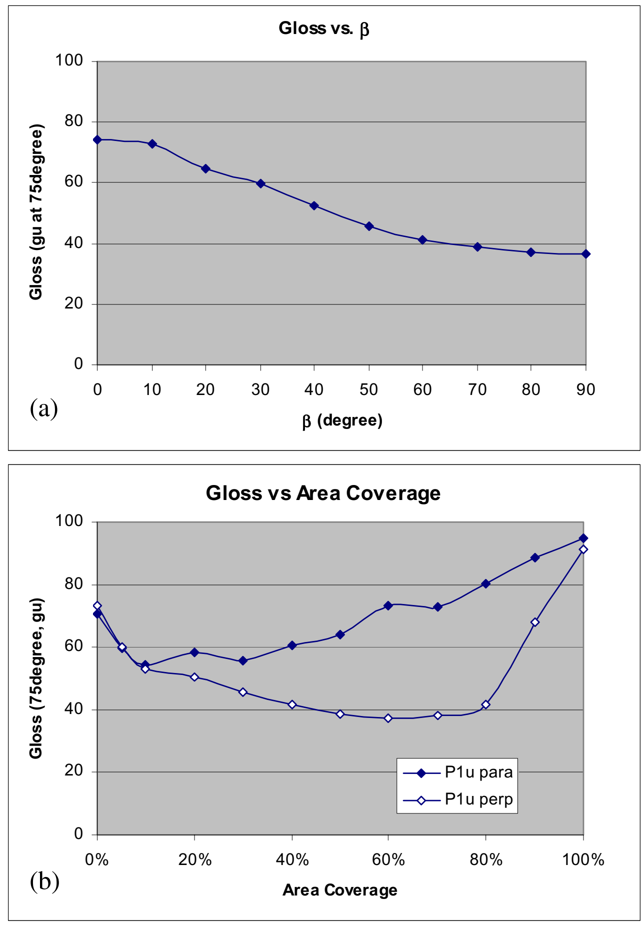

Figure 2. Gloss of Anisotropic Halftone Images

The gloss differential illustrated in Fig. 2(a) is caused by anisotropic halftone structures. As the halftone density changes, the surface structures will change accordingly. Figure 2(b) illustrates how the halftone densities influence the gloss contrast between the parallel and perpendicular configurations. As 0% density, the gloss is just a measure of the substrate's specular response. At 100% density, the reflection is dominated by the toner materials which are laid down uniformly. In both cases, halftone played no role and the gloss responses are isotropic (zero contrast). In the midtone region (40%~80%), halftone induced surface roughness maximizes and causes significant orientation dependent gloss variation. In fact, anisotropic halftones within a wide range of tone levels (20% ~95%) can induce significant orientation dependent gloss. This is the physical foundation of Glossmark™ technology.

Glossmark™ Technology

Glossmark™ Technology Overview

So far, we have shown that the reflective characteristics of some halftones may be dependent upon their azimuth orientation to the light source. Such reflective characteristics when maximized are exhibited in a halftone with a structure which is strongly anisotropic in nature, such as line screens. In other words, the gloss property used to express the light reflected from a halftone clusters will maximally vary depending upon the halftone cluster's azimuth orientation to the light source when that halftone has an anisotropic structure. Although this behavior can be observed when we simply rotate the halftone image under fixed lighting and observing conditions, the visual difference between the two orientations are getting attenuated due to visual memory lose during the configuration switching. Alternatively, we can manifest the visual impact by rendering and printing two image portions with two strongly anisotropic screens that orient very differently. The differential in gloss between the two portions of the image that have been rendered by two different screens is what makes a halftone modulated image a Glossmark™ image.

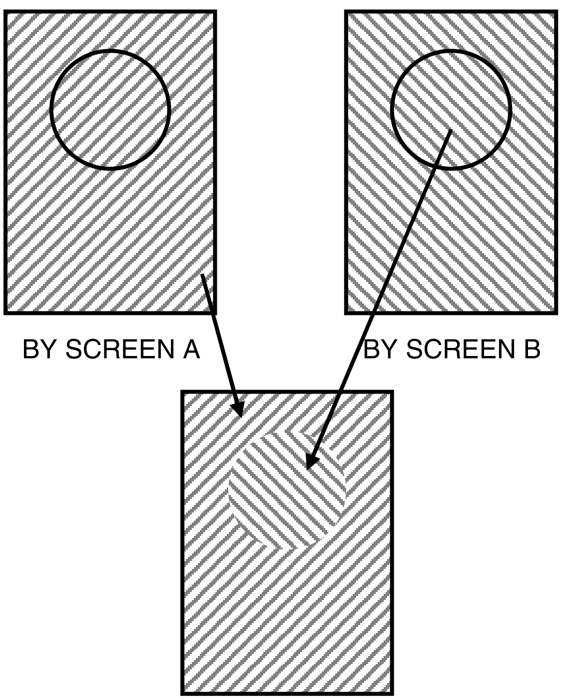

Figure 3. Illustrated Glossmark™ Image Embedding Process

Figure 3 depicts the process of embedding a Glossmark™ image with in another color/grayscale image. Two simple line-screen (screen A and screen B) halftones of anisotropic nature are presented in two orientations. To embed a Glossmark™ circle within a rectangle, the circle is rendered by screen B while the rest of the rectangle area is rendered by screen A. In this manner, selections of the two screen types are patch-worked together to create the Glossmark™ image. Both halftones are selected to be similar in density so that under regular viewing conditions, the circle would be invisible in the midst of a uniform rectangle. If as printed, a mass of the right diagonal line halftones are butted directly adjacent to a mass of left diagonal line halftones, there will be a difference in reflected light between them, which when viewed from an angle will be perceived as a shift in gloss differential or a Glossmark™. The perceptibility of this gloss differential will be maximized when the halftone anisotropic orientations are 90 degrees apart as shown in the example.

In figure 4, one sample Glossmark™ document is shown. The top image is the snapshot of the primary image using regular diffuse lighting (the original is in color) and there is no trace of the Glossmark™ image. The bottom image presents the specular view of the document in which the embedded Glossmark™ image dominates the scene.

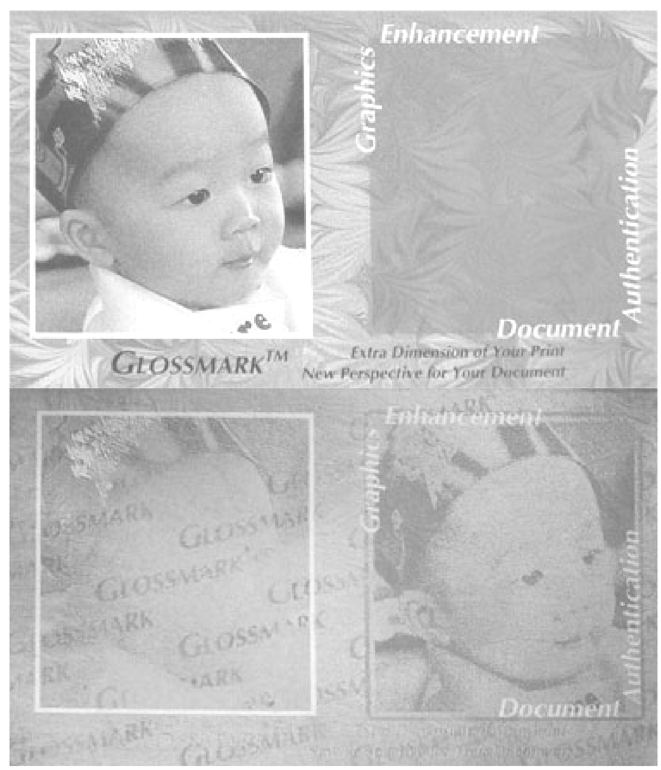

Figure 4. Diffusive and Specular Views of a Sample Glossmark™ Document

Attributes of Glossmark™ Technology

Glossmark™ image is a high contrast optical variable differential gloss image. Glossmark™ technology is the printing process that embeds a Glossmark™ image within a high quality color primary image. With proper rendering and marking processes, the primary color images have very little quality degradation, no interference from the embedded Glossmark™ image under normal viewing conditions. Meanwhile, the Glossmark™ image can possess high contrast within a wide range of colors and densities of the primary images. Viewing directions around the specular reflection enable good separation of the Glossmark™ image from the primary image.

With electrostatic printing as the marking process, Glossmark™ technology is also a true digital printing technology. The integrated Glossmarking process which includes digital workflow, optimized robust digital rendering and digital marking, is capable of variable data/image not only for the content of the primary image but also for the Glossmark™ image. It also enjoys other digital printing advantages such as short run and fast turn around.

Traditionally, a gloss image can be created through spot varnishing, in which a layer of clear toner/ink/varnish is applied to a print according to a varnish image input. Although the gloss images created with spot varnishing appear similar to Glossmark™ images, there are many differences between the two technologies. First, the Glossmark™ images look different from the simple gloss images. Glossmark™ images are orientation dependent differential gloss images. The gloss of a certain area changes with lighting conditions and document orientations. In other words, the areas appear glossy under one condition may look matt under other conditions. Glossmark™ image contrast can be inverted when viewing conditions change and it is an optical variable image. Second, the processes for the two technologies are fundamentally different. Spot varnishing is an extra step after regular color printing and uses special clear ink (glossy or matt) to create the reflective contrast. Glossmark™ imaging is a single step printing process during which both the color image and the Glossmark™ image are created simultaneously. It utilizes the existing ink/toner for color printing and produces the Glossmark™ image through the interaction between the halftone modulation and image surface roughness modulation.

With the capability of superimposing a gloss image onto a color image, Glossmark™ technology can significantly enhance the appearance of a print with ease. Just like other optical variable images, capture of the Glossmark™ image through scanning is very difficult due to the optical variable nature of the Glossmark™ image. Well-designed quality Glossmark™ images are also ideal for document authentication.

Conclusion

In conclusion, we have illustrated the orientation dependent gloss for images created with anisotropic halftones. Combining halftone modulation with this orientation dependent gloss, a new technology known as Glossmark™ technology have been demonstrated. It creates a high quality color graphics and a visually striking Glossmark™ image in a single printing step with no extra toner or special paper. Both the primary image and the embedded Glossmark™ image can be distinctively viewed from different perspectives with little interference. The Glossmark™ technology is ideally suitable for document authentication and graphics enhancement. Its digital implementation provides a capability to embed variable data as digital watermarks into individual prints quickly and economically.

References

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2. B. Xu, S. Wang & C. Liu, US Patent Application 20040000786 (2004)

Biographies

Chu-heng received his Ph.D. degree in physics from the University of Chicago in 1993. After two-year postdoctoral work on light scattering at Exxon Corporate Research, joined Xerox in 1995 with background in granular materials and complex fluids. Research work since joining Xerox covers a broad range of xerographic subsystems including transfer, development, fusing, cleaning and liquid toner related processes. His recent work concentrates on the integration of xerographic materials & processes, and systems analysis. He currently holds more than 30 US patents.

Shen-ge Wang is a principal scientist with Xerox Corporation. He received a BS degree in Instrumental Mechanics from Changchun Institute of Optics, China, in 1970 and a Ph.D. degree in Optics from University of Rochester in 1986, respectively. His current research includes digital and optical image processing, halftoning and printer modeling.

Beilei Xu received her Ph. D degree in medical physics from the University of Chicago in 1999 with a research background in medical image processing and image reconstruction. After joining Xerox Corporation, she applied her expertise in image processing to various printing applications. Her current research interests include image rendering, image processing, and image-based controls.