Authenticate Digital Prints with Glossmark™ Images

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Abstract

Glossmark™ technology is a digital watermarking process that embeds a visually striking gloss image within a high quality color print without the need of a special paper or toner. It utilizes the angular dependence of image gloss to create a differential-gloss image through the modulation of halftone structures. Both the primary image and the embedded Glossmark™ image can be distinctively viewed from different perspectives with little interference. The strong directional nature of the gloss and the subtle halftone modulation process make Glossmark™ images very difficult to detect by a scanner and even more challenging to reproduce through scanning and printing. Its distinct visual effect which is highly desirable for security printing makes it stand out among various halftone modulation technologies. Its differential gloss appearance which originates from the image surface roughness modulation offers better protection against counterfeiting than technologies that utilize only "plain" halftone modulations. Well-designed quality Glossmark™ images are optical variable devices (OVD's) ideally suitable for document authentications. Its digital implementation provides a capability to embed variable data as digital watermarks into individual prints quickly and economically.

Introduction

The advancement of digital scanning and printing has made high quality color available and accessible to everyone. As a result, the effectiveness of color as one of the security components in a secure document has greatly deteriorated. Counterfeiting activities surged in recent years and they are mostly attributed to digital scanning and printing.

Optical variable ink (OVI) and optical variable device (OVD) are security features whose appearances vary with different illumination and viewing configurations. OVD/OVI examples include holograms, optical variable metallic inks, intaglio printing features, various transparent (or white) inks that modify the optical properties of the substrates, and etc. They are highly valued in security printing because these features are easily detectable without any special devices. Their visibility without any visual aid offers invaluable first line defense against counterfeiting. They are also very effective against scanning and printing due to their optical variable nature, because a typical scanner and printer are designed to faithfully capture and reproduce one snapshot of a document. OVDs' native variable appearances are very difficult to capture and are even more challenging to reproduce with regular printers.

The demand for protection of digitally printed documents against fraud also increased in recent years due to the ubiquitous use of digital printing. Compare to traditional security documents, digitally printed documents are even more difficult to secure due to several factors. Digital prints are more likely to be produced through distributed digital printing. How to offer on-demand protection to on-demand printed document is a new challenge. It is also generally true that a digitally printed document can be digitally reproduced without any fundamental barriers. Traditional OVDs are effective but are generally incompatible with digital printing. Therefore, pre-processing of the substrate or post processing of the printed document is typically required to meet the security requirements.

Glossmark™ Technology Overview

The physical foundation of Glossmark™ technology is the orientation dependent gloss appearance of anisotropic halftones created through certain marking processes. Gloss is typically isotropic for most surfaces since there is no preferred direction for the surface structures. It has not been well appreciated that certain printing can induce orientational roughness to the surfaces of printed matter and cause differing reflective characteristics depending upon the orientation of the halftone with respect to the lighting.

Figure 1 illustrates one such example which is a 200lpi line screen patch produced by a xerographic printer on LustroGloss substrate. It is evident that the direction of the lines breaks the in-plane isotropic symmetry of the substrate. Instead of the in plane density distribution, what is relevant to the specular reflectivity is the surface roughness. As a by-product of the halftoning which creates the line pattern of the in-plane density variation, the image surface also acquires the anisotropy through the marking process (toner deposition and fusing). Consequently, this anisotropic surface roughness can cause orientation dependent gloss.

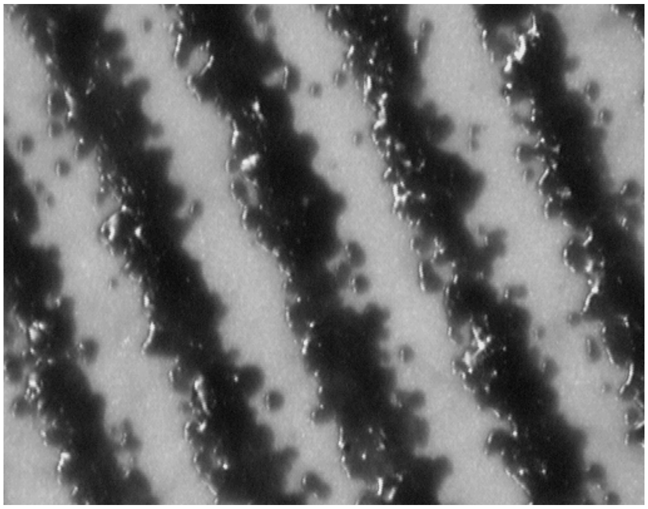

Figure 1. Microscopic Structures of Xerographic Line Screen Halftones

Glossmark™ technology utilizes this orientation dependent gloss to embed a secondary image, known as Glossmark™ image. Figure 2 shows one exemplary implementation of Glossmark™ image. In the midst of the background which is rendered with vertical lines, the intended Glossmark™ image (the circle) is rendered with horizontal lines. When the screens are chosen to have matched density, the embedded Glossmark™ image would be invisible under regular diffusive viewing conditions.

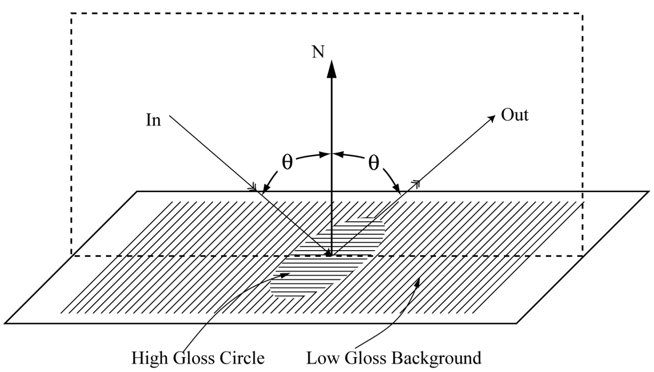

Figure 2. Illustrated Glossmark™ Image Embedding and Viewing Processes

To examine the embedded Glossmark™ image, simply look for the specular reflections from the image surface. As shown in the illustration, the circle would appear to have higher gloss than the background. We call the viewing/measurement conditions for the image and background areas parallel and perpendicular configurations respectively according to their line orientations with respect to the illumination/detection plane. As we rotate the image, the observed difference in gloss between the two regions varies in response to the orientation change. At 45°, the gloss contrast disappears completely due to symmetry. After 90° rotation, the contrast is then inverted because the image and background areas have just exchanged their measurement configurations. This is the optical variable nature of Glossmark™ images.

Glossmark™ Images: A New Perspective from the Extra Dimension of Your Document

Although Glossmark™ is implemented through halftone modulation, its visual effect originates from the image roughness variation which is a secondary effect of halftone modulation during some marking processes. This structural variation in the third dimension (the roughness) not only provides brand new visual perspective for a print but also establishes an extra level of document protection against counterfeiting.

Gloss measures the specular reflection from a surface. In general, smoother surface gives rise to higher gloss. It has to be noted that this smoothness has to be measured by the wavelength of light which is around a fraction of a micrometer. In addition to the magnitude of the roughness, the variation of the surface profile across the plane is also of great importance. The roughness in the length scales ranging from submicron to macroscopic sizes such as hundreds of microns can all have significant effect on the final specular reflective responses of the surface.

Let's take another look at Fig. 1. The roughness of the substrate is invisible under the current magnification. This coated stock has roughness around the order of a micron. In addition to the anisotropic halftone patterns, the grainy structure of individual toner particles which have the size of 5~10 um is clearly present. Another important length scale which is not directly illustrated here is the microscopic smoothness of the toner surface which will govern the gloss of solid areas.

Challenges to Create Quality Glossmark™ Images

Quality is essential to security printing. Low quality implies that there could be many ways to meet the specs. Therefore, without sufficient quality, the security would have been compromised. When apply Glossmark™ to security printing, the quality has to be assured as well. Glossmark™ technology involves two images: the primary image and the embedded differential gloss image. For good document protection, both high quality primary and Glossmark™ images are need to be present simultaneously. In the following subsections, we will discuss the challenges associated with embedding a quality Glossmark™ image within a high quality primary image. It is noted that the difficulties related to the creation of this security feature will also be the challenges the counterfeiters have to face in the future.

Marking Process

This is the technology element that sets Glossmark™ technology apart from other halftone modulation related security printing methods. The key attributes for this technology selection is the magnitude of orientation dependent differential gloss. Great contrast not only allows convenient visual authentication, but also enables more security feature designs for better protection. Currently, electrostatic printing is the most promising marking process for Glossmark™ technology.

Although it is strange that a copier's technology is selected for anti-copy applications, it will become evident that a Glossmark™ capable electrostatic printer is well-suited for document authentication.

Figure 3. Scanned Image of a Glossmark™ Image Created with EP Process

Digital Imaging

The actual watermarking of Glossmark™ technology is carried out through halftone modulation. One simple & effective halftone modulation method for Glossmark™ is SAM (Screen Angle Modulation). Typically, a strongly anisotropic base halftone is selected, for example, a line screen or an elliptical dot screen. The modulated screen is obtained through a simple rotation of the base screen. SAM has been widely used for security printing. The halftone angles are modulated without introducing significant density/color artifacts and a SAM document is typically printed with printing presses. The basic quality goals for screen modulations are: 1) density/color matching: no density/color variations between the original and the modulated screens across all density ranges; 2) seamless screen switching: no boundary artifacts when halftone switch patterns at the Glossmark™ images edges. The boundary is the region where the halftone structures are subject to the most interruptions.

Screen angle modulation is a mature technology for other printing technologies, but it is still a challenge for electrostatic printing. Xerographic marking is a very non-linear (not a high fidelity) process during which the digital input is significantly modified. The details of the physical output, such as the halftone cluster profiles, looks very different from its digital form. The physical dot gains, adjacency effect are very strong and are also orientation dependent. For example, fine lines in the process direction are developed with different physical characteristics than fine lines across the process direction. Adjacency effects such as dot merging and line growth are particularly sensitive to the detailed non-local image structures. Figure 3 shows one of the potential defects associated with an electrostatic print of a screen angle modulated image patch. Along the edges of the embedded Xerox logo, the density appears darker due to interruptions to the halftone structures and the typical high level of dot gains associated with EP processes.

Although it is conceivable to use sophisticated printer model, detailed calibration and complicated digital image processing to achieve the density matching and seamless screen switching, it might be too difficult for any practical implementations. Furthermore, a xerographic system is typically not very stable and frequent calibrations/controls are required to bring the quality within specifications.

We explored the opportunities for a robust halftone design which is less sensitive to the xerographic noises and variations. The search for a robust Glossmark™ screen design starts with the interaction between the digital input and the physical output. Taking advantages of the insights gained through these investigations, we derived a series of halftone screen sets which are very robust against xerographic noises and dot gains. Details of some sample screens can be found in Ref. 1. With a robust screen design, very little maintenance/calibration are required to achieve excellent density/color matching and seamless screen switching. In addition, the fact that no image processing is required implies fast rendering that can keep pace with digital printing's variable data/image capability.

Figure 4 shows another high resolution scan of the halftone pattern of a Glossmark™ containing image. The embedded Glossmark™ image is a circular disc centered in the patch. Taking advantage of the great differential gloss contrast of the EP process, very subtle halftone modulations are used to produce the Glossmark™ image with sufficient contrast for visual inspection. It has no visible artifacts and hardly shows much halftone modulation. A well designed Glossmark™ document which can incorporates various security features can be a great challenge to any scanning and printing counterfeiting approaches.

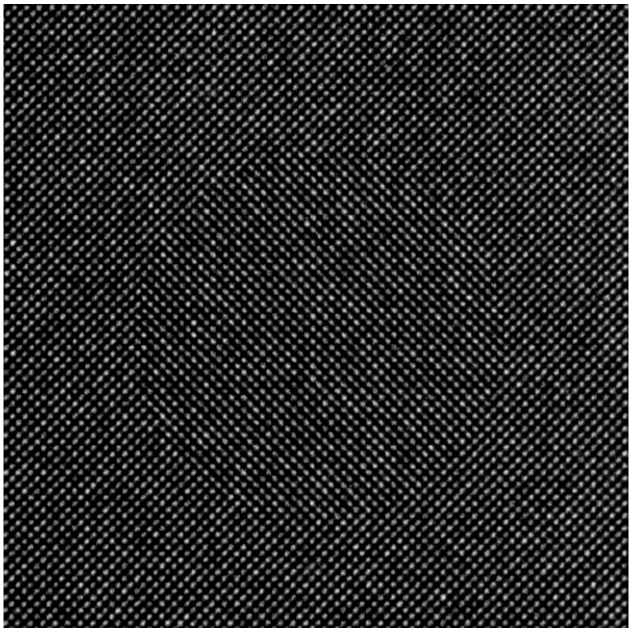

Figure 4. Scanned Image of a Glossmark™ Image (a Disc) Created with Subtle Halftone Modulation

Workflow

Electrostatic printing is a digital marking process. Combined with robust Glossmark™ halftone design, an efficient digital printing workflow is formed. It enjoys the typical digital printing advantages such as short run and fast turn around. It is also capable of variable data/image not only for the content of the primary image but also for the Glossmark™ image. This on-demand, dynamic Glossmark™ OVD presents an even greater challenge to the counterfeiters than traditional static OVDs do.

Glossmark™ Technology against Various Counterfeiting Threats

The most common threats against printed document are copying (scanning and printing). Regular scanning is intended for diffusive response of a print and not suitable for Glossmark™ image capture. Even if the scanner is modified to capture Glossmark™ images, it can scan only one view of the Glossmark™ OVD. The usefulness of high resolution scanning in counterfeiting of Glossmark™ document is also very limited. As illustrated in figure 1, EP process is inherently noisy and non-linear, reverse-engineering the EP halftone cluster is much more difficult than offset. Furthermore, with very subtle screen modulation, the signature of the modulation is hardly visible in the presence of the inherent noise of EP marking, as figure 4 illustrates.

Even if the counterfeiters have succeeded in capturing the high resolution halftone structures, directing this high resolution image through a digital printing workflow is the next challenge. Unlike offset printing and imagesetters, digital printing does not faithfully accept high resolution inputs. Digital images from the input are typically subjected to descreening, compression, scaling and/or re-screening. Any of these processes will destroy the halftone structures.

The marking materials and processes play another critical role in the protection of a Glossmark™ document. Without the extra dimension of the image, there is no Glossmark™ image and only plain halftone modulation will remain. The marking process that enables Glossmark™ image is still not well-understood. Glossmark™ images created with one model of EP machines may appear very different from the output of another printer. This can also serve as an advantage for security printing.

Another threat can potentially come from spot varnishing. 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 them and should be evident with proper caution. 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.

Conclusion

Glossmark™ is a new type of optical variable device (OVD) suitable for security printing. One of its digital variants which employs electrostatic printing, digital rendering and digital workflow, enables on-demand OVD with variable image/data. Although the original Glossmark™ images can be created with digital printing, quality Glossmark™ OVDs are very effective against the common threat of digital copying (scanning & printing).

References

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Biographies

Chu-heng Liu 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.