Automated Optimization of Void Pantograph Settings

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Abstract

Void pantographs (VPs) have been an important part of the security printing toolkit for several decades. When crafted for a specific printing technology, VPs provide an almost "magical" effect—they are nearly invisible in the original print and then stand out strikingly when they are copied. However, this effect comes at an expense—VPs have historically been designed only for a specific printing technology, and so cannot be extended to a mobile-printing world, where the VP needs to be supported by a wide range of printers.

In this paper, we describe an automated process for optimizing the VP settings. These are the background and foreground pattern used in the VP—the background "disappears" when copied and the foreground "bolds". VP test sheets are created using the ranges of background and foreground settings necessary to guarantee identification of at least one "readable" pair of settings. This can be automated by writing the VP as a readable mark—for example, a barcode that can be read (or not read) by a barcode reader; text that can be read (or not read) by an optical character recognition (OCR) engine; or even a face that can be recognized by a face recognition engine. The successful VPs will not be readable (using camera images to prevent a "copying" effect) when originally printed but accurately readable (using a camera) after a single copy, or print-scan, cycle.

Keywords*: Copy Evidence, Covert Printing, Print-Scan Cycle, VDP*

Introduction

Void pantographs are used to create copy-evident backgrounds for a variety of security documents. Perhaps most prominently, void pantographs are used as backgrounds for checks, sometimes for example displaying "void" or "copy" on the reproduced image yet being minimally visually perceptible in the original. One of the first embodiments of the void pantograph (VP) involved the use of two dot patterns of differing sizes to allow a desired message or image to appear when an original document was copied or scanned. This approach, known colloquially as "big-dot-little-dot" technology, works by playing off the physical limitations of the optical systems in copiers and scanners. The little dots are sized below the optical resolution and thereby disappear or fade when copied while the larger dots are preserved during the copy process and subsequently visually standout due to the increased difference in contrast [1].

Traditionally these void pantographs have been generated using industrial lithographic printers which provide consistently high quality images and are capable of rendering VPs in any desired color by selection of the appropriate spot ink. More recently, companies have begun to generate VPs using digital printing processes [2]. While both approaches provide a means for producing high volume high quality runs, these approaches only generate a single VP pattern for a given print run.

Other approaches to copy-evident patterns make use of specific proprietary patterns or substrates; see, for example, references [3][4]. In these approaches, the copy-evident patterns are embedded into the substrate and content is subsequently printed in a separate print run. Checks, passports and property titles are common exemplars for this method. The background anti-copy pattern contains a static message and the variable content stores identity, address and other relevant information specific to the application.

In this paper, we examine an alternate approach for utilizing the void pantograph copy-evident pattern. Specifically, we investigate a method whereby the VP can be calibrated to function on any printer. This allows the user to change where in the print workflow the VP can be inserted. Instead of requiring the VP to be printed on to the substrate at the beginning, the VP can be printed at any point in the work flow and any message or image may be selected for use. This approach extends the VP into the realm of variable data printing (VDP) and gives the user broader flexibility in selecting anti-counterfeiting deterrents as part of a broader security and deterrence campaign.

Methodology and Results

1. Settings Determination

Our approach to implementation of the VP is performed in several steps. We briefly list the steps to give the reader an overall sense of our approach and then go into further detail below. (1) A test sheet is digital image generated that is comprised of multiple instances of the VP to examine a range of possible settings. (2) The test sheet is printed on all target printers on which the user wishes to deploy the VP pattern. (3) The printed test pages are photocopied to examine which combination of settings achieves the desired effect for each printer. (4) The copied test sheet is then compared to the original printed test sheet to identify the settings which effectively hide the VP test pattern when printed but reveal the test pattern when copied.

The void pantograph is produced by using differential dot sizes and differential black pixel concentrations. For 600 dots per inch (dpi) printers, we used 2x2 pixel dots (foreground) and 1x1 pixel dots (background) for the dot sizes. Then, we vary the percentage of black ink coverage by varying the density of dot placement. We emphasize that our approach to construct the VP pattern is purely binary. That is, all dot patterns are rendered as pure black on a pure white background. Figure 1 illustrates the use of the two dot sizes by showing a scaled-up example of the approach.

The test sheet used in our approach is constructed of 9 rows and 7 columns of a test pattern at varying foreground and background intensities generated at 600 ppi. Figure 2 depicts a scaled down example test page. The test pattern is a simple cross ("+") centrally placed within a one inch square test patch (though any pattern or text could be used which is of sufficient size to embed a VP pattern). From left to right across the test page, the foreground pixel intensity increases (from 4% to 16% in Figure 1) and thus the intensity of the cross increases. The change in the background intensity is computed relative to the value of the foreground. Each row is assigned a multiplier value (ranging from 0.40 to 1.60 in Figure 1) and the background intensity is computed as the product of the foreground and the multiplier value. Dots are then randomly placed within the foreground or background to achieve the target percentages. Figure 3 shows an example test cross enlarged for better visibility, created from the above process.

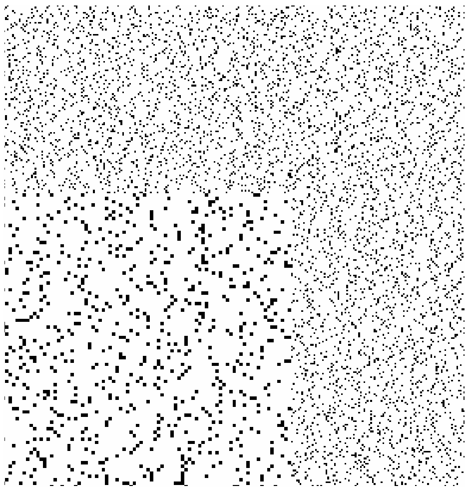

Figure 1. *Same black pixel density (10%), different dot cluster size (2x2 at 600 dpi in lower left, 1x1 at 600 dpi in rest of image).*

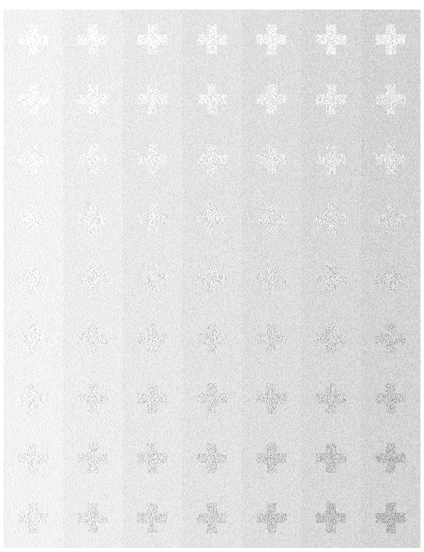

Figure 2. *Scaled representation of the void pantograph test sheet. Actual size is 7" W by 9" H at 600 ppi.*

The test page is then printed on each target printer to be examined. The printed pages are subsequently copied using either an all-in-one multi-function printer or a commercial copier. The nominal set of foreground/background values will result in the test cross being only minimally visually perceptible in the original print, but highly prominent once copied. Inspection of both the printed test sheet and copied test sheet allows one to identify these settings. In some cases, the initial range of foreground and background intensities may be too broad to fully elicit the VP effect. In this case, one may use the first sheet as a "coarse" calibration to identify a smaller range of settings from which to produce a second test sheet for finer granularity.

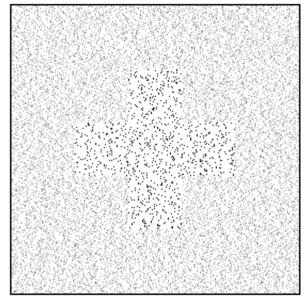

Figure 3. *Original image of a VP test pattern enlarged for legibility.*

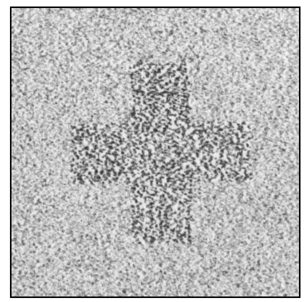

Figure 4. *Digital camera photograph of a copied test pattern enlarged for legibility. Note how the cross stands out from the background after copying.*

2. Pattern Detection & Recognition

After the void pantograph deployment candidates are chosen, the actual patterns to be used are chosen. Different shapes will be used for different workflows, as described below. The void pantographs are then printed as a background to whatever the foreground is (of course, the parts to be read should not be obscured, or "hidden", by whatever else is printed in addition to the void pantograph).

After scanning, the void pantograph stands out (Figure 4) to the human eye, and is also readily identified with existing segmentation software. Selecting the latter option to identify the VP enables the use automated workflows. Once the pattern is identified, the pattern can, in the case of OCR, be read and acted upon based on the content in the text. The steps for enabling these options are further detailed in steps 3 and 4.

When utilizing an automated machine vision approach for identification, the steps to form the void pantograph patterns from the scanned image are as follows:

a. Threshold the image (this "binarizes" it, leaving the ink areas black and the non-ink areas white).

b. Perform erosion of the resulting connected components. This completely erases the small dots and shrinks, but does not erase, the large dots. Generally, 1-pixel boundary erosion suffices for this step (even if a few small dots are not erased completely, they will not result in substantial regions of interest in Step 4 below.

c. Perform dilation of the remaining connected components. This returns the larger dots to their original size (but does not reconstitute the small dots, since they have been erased).

d. Form regions of interest from the remaining dots. Here, run length smearing [5] (by the square root of the inverse of the black percentage of pixels) is used to cluster the dots left over into their original associated shapes or forms.

3. Region Analysis

These regions of interest are then analyzed based on their typing. If classified as text, for example, OCR (optical character recognition) is used for interpretation. If classified as shapes, shape analysis (such as Freeman, or chain, coding [6]) is used for interpretation, etc. Any type of pattern recognition suitable for the embedded pattern can be used at this stage.

We are experimenting with two types of multiple void pantographs. The first is where different regions of interest are encoded with different "foreground" specifications—e.g. different relative percent blacks if we are using the smallest set of distinguishable dot patterns (2x2 vs. 1x1) and there is no overlap between them. This is readily achieved with simply choosing multiple distinct foregrounds over a given background—e.g. foreground "%black" = 5%, 6.67%, 8.33%, 10%, 11.67%, 13.33% and 15% over a background of 10%. When using one type of printer, the 13.33% foreground will show best against the background; when using another, the 5% foreground will show best against the background.

The use of multiple regions of interest allows one to deploy a single VP with multiple messages within the VP, each being calibrated to a specific make and model printer. For example, the left-hand side of an image may reveal the message "Printer A" when printed on printer A and copied, but when printed on printer model B reveals no message. The converse can also be configured such that the right-hand side of the VP will reveal a different message when printed on printer B, but not on printer A. Obviously, some analysis of the VP settings is required to find the ideal mix of settings which allow messages to be hidden by both printers prior to copying and also correctly reveal the target message when copied.

The second is where the overlap of two foreground patterns produces the most distinct region of interest after copying (printing and scanning). The effectiveness of this approach is variable, depending on the printer, scanner and substrate (paper) type. We are currently characterizing these dependencies.

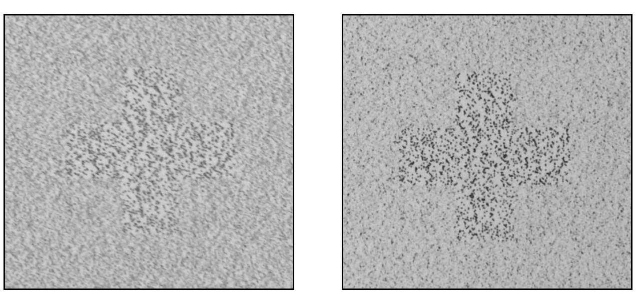

Figure 5. *Two VP test crosses with the same foreground and background intensity settings. The left image was printed on an inkjet printer and the right image was printed on a laser printer. Both images were taken with the same digital camera.*

4. Workflow Design

In the last step, the information that is read then sets into motion the correct workflow. This step can be automated on a copier, since the "copied" image is directly scanned by definition during the copy process. With more and more commercial copiers containing network functionality, a number of options are available. Applications readily amenable to setting automated workflows into motion include: document routing, document indexing, and document workflows.

1. Authentication workflow: if the document is not intended to be copied except on one type of copier, the variable void pantograph will pop up with a denial of copying message (and could send an appropriate alert). Only the variable void pantograph associated with the correct copier will not instantiate this workflow.

This approach can be enabled by several means. For example, if a specific message (payload) is embedded in the VP a multifunction copier can scan the document, extract the message from the VP, perform a database lookup to determine the appropriate action, and lastly allow or deny copying of the document based on the query returned from the database. (See Figure 6 for a depiction of the workflow.)

2. Differential downstream image pipeline/restoration dependent on the type of printer it is. In this case, the void pantograph sheet is the first sheet printed and inspected in a test run, and is used to determine the print job settings. The void pantograph that best stands out from the background (has the best OCR or shape matching score) is read and used to determine the settings for the rest of the inspection-related printing job.

3. Other uses, such as imposing differential security, privacy, biometric, etc. policies depending on the type of copier (which is automatically determined from the set of variable void pantographs), are readily understood at this point.

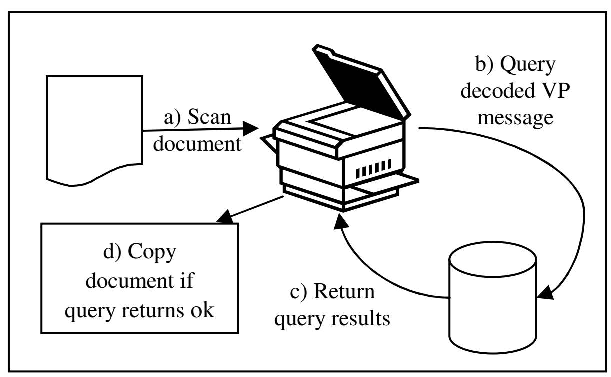

Figure 6. *Document workflow based on the information contained within the void pantograph.*

Discussion and Conclusions

The use of calibration test sheets allows for rapid testing of multiple printers to be used in deployment. Since technologies and print engines vary between models and brands of printers, it is a necessary step to determine optimal settings for each printer to be used in a workflow. Simply looking at the differences between thermal ink jet (TIJ) and dry electrophotography (DEP) printers (i.e. laser printers) when printing on the same substrate illustrates this point. See Figure 5 for an example. Unlike laser printers, TIJ printers will have increased ink spread on pulped substrates. This spread will affect which combination of settings best elicits the VP effect. Other differences, including the amount of ink or toner deposited, will affect the intensity of the patterns and the subsequent contrast differences. Similarly, if more than one type of substrate is to be used, calibration sheets should be printed for each substrate. Just like the differences between DEP and TIJ printers, different substrates may have different surface chemistries which alter how the ink or toner diffuse or adhere to it.

In addition to the copy-evident patterns that void pantographs are known for, there is clearly other utility in the VP which can be incorporated into workflows. As an alternative to the barcode, the VP can carry text or an image as payload which is specifically calibrated to a target make and model printer. If a document containing a VP is printed on an unauthorized model printer the VP pattern will be attenuated since it was not specifically calibrated to the printer in question. Unlike other security or payload-carrying marks, the VP requires no special hardware for reading and is easily discoverable by anyone handling a document or certificate on which the VP is printed.

While void pantographs are not the most robust of security deterrents available today, their ease of implementation and ability to be used as both deterrent and payload carrier make the VP a valuable instrument in security and automated workflows.

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Author Biography

Jason Aronoff received his MS in Computer Science from Colorado State University in 2008. He has been working full time for HP Labs since the beginning of 2007 when he joined what has now become the Security Printing and Imaging group. His work has focused on deterrent qualification and functional printing as applied towards anti-counterfeiting techniques. He is a member of IS&T, IEEE, and ACM.