Barcode Structural Pre-Compensation Optimization

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Abstract:
Barcode print payload density is significantly improved when the effects of the print-scan (PS) cycle are anticipated in the barcode elements before printing. The PS cycle generally causes dot gain, and thus the black portions of the barcodes expand relative to the white portions. Structural pre-compensation (StructPC) anticipates this effect by removing black pixels from the boundaries of the black elements (modules and calibrating sections) of the barcodes. In this paper, we varied the amount of StructPC from 0 to 6 pixels for 2D DataMatrix barcodes that were printed at 600 dpi. Module sizes were varied from 10 to 30 mils (6 to 18 pixels at print resolution), using ECC 200 (~30% error correcting code). Test sets were printed on four types of printers. Each printer set underwent 2 additional PS cycles. We evaluated the optimal StructPC for each printer type after the combined 1, 2 and 3 PS cycles. We used the same substrate (office paper) throughout. Our findings support the implementation of StructPC for 2D barcodes. For every printer, the smallest readable barcode size was obtained with StructPC applied. StructPC results were printer-dependent: optimally 2 pixels for the dry electrophotographic printer, and optimally 2-5 pixels for thermal inkjet printers.

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Abstract

Barcode print payload density is significantly improved when the effects of the print-scan (PS) cycle are anticipated in the barcode elements before printing. The PS cycle generally causes dot gain, and thus the black portions of the barcodes expand relative to the white portions. Structural pre-compensation (StructPC) anticipates this effect by removing black pixels from the boundaries of the black elements (modules and calibrating sections) of the barcodes. In this paper, we varied the amount of StructPC from 0 to 6 pixels for 2D DataMatrix barcodes that were printed at 600 dpi. Module sizes were varied from 10 to 30 mils (6 to 18 pixels at print resolution), using ECC 200 (~30% error-correcting code). Test sets were printed on four types of printers. Each printer set underwent 2 additional PS cycles. We evaluated the optimal StructPC for each printer type after the combined 1, 2 and 3 PS cycles. We used the same substrate (office paper) throughout. Our findings support the implementation of StructPC for 2D barcodes. For every printer, the smallest readable barcode size was obtained with StructPC applied. StructPC results were printer-dependent: optimally 2 pixels for the dry electrophotographic printer, and optimally 2-5 pixels for thermal inkjet printers.

Introduction

Structural pre-compensation [1] has been introduced as a method of anticipating printing-related effects on ink/substrate interaction. However, previous work has not explored how structural pre-compensation (StructPC) is optimized for a given printer/substrate combination, nor examined the effect of StructPC on the PS, or copying, cycle [2]. We present the results of an experiment designed to find the optimal StructPC for each of 4 different printers using HP office paper. The design included consideration of the effects of the print-scan cycle by copying printed test sheets.

Experiments Performed

Structural pre-compensation (StructPC) removes black pixels from the boundaries of the black elements (modules and calibrating sections) of the barcodes. In our experiment, we varied the amount of StructPC from 0 to 6 pixels for 2D DataMatrix[3] barcodes that were printed at 600 dpi. Test pages were created by varying the size of symbols, consisting of 23 character payloads. We used DataMatrix symbol sizes from 10 mils to 30 mils (254-762 micrometers (μm) or 6 to 18 pixels at print resolution) with ECC200. The error correction percentage was approximately 30%. Five barcodes of each size were generated using B-Coder Bar Code Graphic Generator, Version 4.0 [4].

The generated test pages where then printed out on each of four different printers on HP office paper: HP Color Laser Jet 3600, HP Desk Jet 6940, HP PhotoSmart C6280, and HP Desk Jet 6127. Once printed, the test pages were copied using a HP Laser Jet M9040 MFP with normal settings. To generate a second generation copy, we then copied the pages created by the first copy.

The barcodes were read using an InData Systems LDS-4600 reader with 405 nm w.p.e. LEDs for its light source. Successful reading of all five barcodes of each size and within one second was required to consider the tested size as "readable"

Results

The following tables contain data collected from reading barcodes on the test sheets. These tables contain the smallest readable symbol (in mils) for each tested printer as well as for the first and second generation copies of the test pages.

Table 1: Readability Values Different Printers – No Pre-Compensation

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	14	13	12
DJ 6940	14	13	12
PS C6280	17	14	14
DJ 6127	19	18	14

Table 2: Optimal Structural Pre-Compensation (StructPC) Values for Different Printers, 1-Pixel Precomp

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	12	10	10
DJ 6940	13	13	12
PS C6280	15	14	13
DJ 6127	16	14	14

Table 3: Optimal Structural Pre-Compensation (StructPC) Values for Different Printers, 2-Pixel Precomp

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	10	10	10
DJ 6940	10	10	10
PS C6280	14	12	12
DJ 6127	14	13	13

Table 4: Optimal Structural Pre-Compensation (StructPC) Values for Different Printers, 3-Pixel Precomp

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	10	10	11
DJ 6940	10	10	10
PS C6280	12	12	12
DJ 6127	11	11	12

Table 5: Optimal Structural Pre-Compensation (StructPC) Values for Different Printers, 4-Pixel Precomp

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	10	10	11
DJ 6940	10	11	11
PS C6280	12	12	12
DJ 6127	13	12	13

Table 6: Optimal Structural Pre-Compensation (StructPC) Values for Different Printers, 5-Pixel Precomp

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	11	12	12
DJ 6940	11	12	12
PS C6280	11	12	12
DJ 6127	12	12	12

Table 7: Optimal Structural Pre-Compensation (StructPC) Values for Different Printers, 6-Pixel Precomp

Printer	Size of Smallest Readable Symbol (in mil=0.001")		
	Original Print	1 PS Cycle	2 PS Cycle
CLJ 3600	12	13	15
DJ 6940	12	12	15
PS C6280	12	15	15
DJ 6127	12	13	15

The following figures illustrate the effect of the print-scan-copy cycle. Figure 1 contains the curves for actual printed page, while figures 2 and 3 show the curves for the first and second generation copies, respectively.

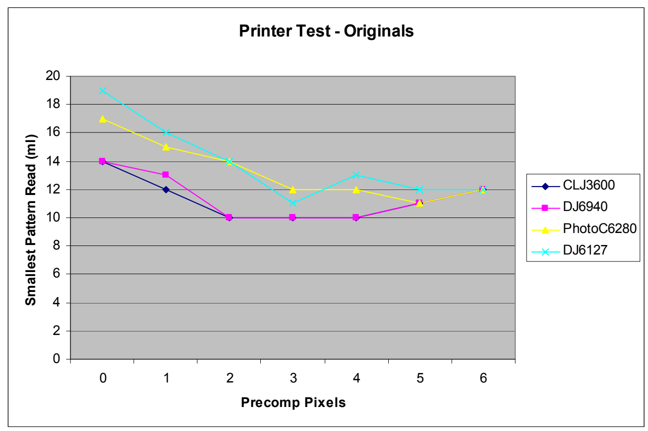

Figure 1. Original printed tests – Smallest symbol (in mils) read for number of pre-compensated pixels.

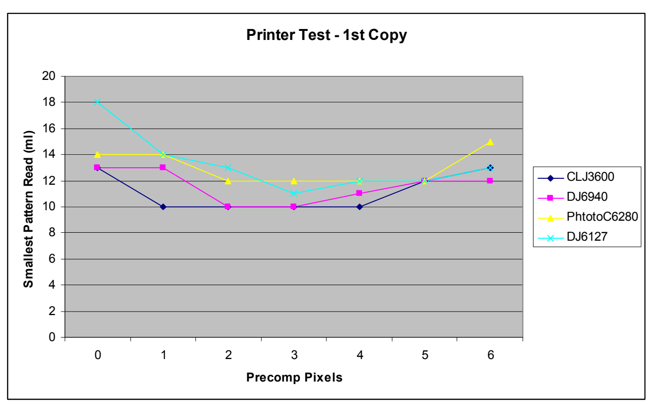

Figure 2. 1st Generation copy tests – Smallest symbol (in mils) read for number of pre-compensated pixels.

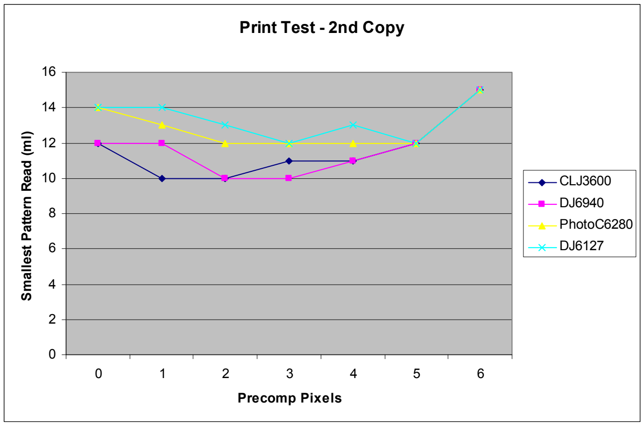

***Figure 3**. 2nd Generation copy tests – Smallest symbol (in mils) read for number of pre-compensated pixels.*

Discussion and Conclusions

Table 1 demonstrates that barcode readability actually improves with 1-2 PS cycles when StructPC is not used. The implications are that, for readability purposes, printing the barcodes without StructPC gives the would-be counterfeiter a "free pass" to make a copy—their copy of the original, in fact, is more "authentic" to a barcode reader. These data indicate that, for the print technologies investigated herein, StructPC is important for brand protection and security.

Table 2 contains the results using single pixel pre-compensation. While the readable symbol size generally goes down (i.e. gets smaller) for all printers and their copies, the reduction is not significant and the problem of readability getting better with the PS cycle is still apparent.

Table 3, showing results for two pixel pre-compensation, is more promising. Not only do readability sizes reach the limit of 10 mils for two of the four printers, copying no longer improves readability for those printers as well. Tables 4, 5, and 6, illustrate the continuing trend of smaller symbol readability for pre-compensation of 3, 4, and 5 pixels. Readability for 1-2 PS cycle generally remains the same or gets worse with pre-compensation.

Tables 6 and 7 demonstrate that pre-compensation above 5 pixels generally decreases readability for the smaller symbol sizes, both for the original print and the subsequent copies. Note, however, readability for the 1-2 PS continues to be the same or worse than the original.

Figures 1 – 3 show the data for the original, first, and second copy tests for each of the printers. The purpose of these graphs is to show that the trend for pre-compensation is similar for all the printers: symbol readability sizes decrease after one pixel pre-compensation until the smallest readable size (10 mils) is the smallest size chosen for this test. Readability size starts to increase after pre-compensation reaches six or more pixels. Therefore, the optimal StructPC was 2-5 pixels for this experiment.

Tables 2-6 shows that StructPC accounts for improved results when the PS cycle is experienced and this should take away the "counterfeiter's advantage". However, even with best StructPC, 1-2 print-scans can generally copy well. This indicates DataMatrix barcodes alone, as specified in the ISO standard [3], cannot generally provide copy deterrence, even with optimal StructPC. StructPC, however, is certainly warranted, as without it, copied barcodes actually read "better" than originals.

References

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Author Biography

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