A Universal Printer Benchmark Test Protocol

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Abstract

Digital printing devices (electrophotographic, inkjet, thermal) are competing fiercely in the digital fulfillment space. Image quality and cost per page are two important yardsticks helping the choice of a device for a given application. What is often overlooked is the robustness of that device under various usage conditions. This paper will discuss a universal benchmark test protocol that is robustness based, and present quantitative ranking of printers' performance. The test can be used for benchmarking printers from several manufacturers, or benchmark new components of a particular printer for quality improvement. We will benchmark specifically several electrophotographic printers. However, the method can be applied to inkjet or thermal printers.

Introduction

Digital printing devices (electrophotographic, inkjet, thermal) are competing fiercely in the digital fulfillment space. Image quality and cost per page are two important yardsticks helping the choice of a device for a given application.

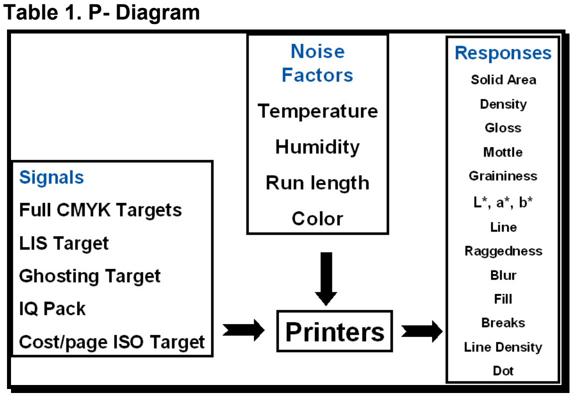
What is often overlooked is the robustness of that device under various usage conditions. The goals of this work include:

Develop a universal benchmark test for comprehensive and quantitative assessment of EP Printers.

Use the developed test to establish baseline performance data for quick evaluation of new components: toner cartridges, photoconductors, fusers, writing heads, image processors, etc.

The developed test is consumable-centric, sizable to printer duty cycle, robustness-based, and expandable in scope. The general philosophy of our test is summarized in the P-Diagram below.

Table 1. P- Diagram



Methods and procedures

This study relies on the cartridge model used by almost every electrophotographic printer manufacturer. The image quality of the printer is renewed and maintained with the replacement of worn cartridges with new one. Thus we base our benchmarking test on the largest capacity cartridge available for each of the printers tested.

Test Mechanics

Each printer was tested at three dew point conditions, 50 ºF, 20 ºF, and 70 ºF. All cartridges were new and the largest capacity available for that printer. The size of available cartridges always reflects the duty cycle of the printer. That fact helps size the test to the duty cycle of the printer. One fourth of the toner cartridge capacity was used for each of the three dew point conditions. The remaining fourth was allocated for generating keepers for image quality evaluation.

The sequence outlined in Table 2 was followed for each of the dew point runs.

Table 2. Test Mechanics

1. Equilibrate Printer and Consumables for 24 hours at appropriate Dew Point
2. Measure Toner Q/M for all 4 cartridges
3. Run all test Targets (Save Six Keeper Sets Each)
4. Measure Toner Q/M for all 4 cartridges
5. Run ISO Cost/page document. Run Length determined by printer duty cycle(largest capacity toner cartridge)
6. Measure Toner Q/M for all 4 cartridges
7. Run all test Targets (Save Six Keeper Sets Each)
8. Measure Toner Q/M for all 4 cartridges
9. End of Condition

Image Quality Evaluation

Our test uses objective image quality metrics, such as line, solid area, and color reproduction.[1] We took full advantage of the ease of use, and data handling of the QEA Personal Image Analyzer[2] to semi-automate image quality data acquisition and analysis. An Access database was used to organize the acquired data. We used Taguchi principles[3, 4] such as the loss functions, and signal-to-noise ratio. A loss function and signal ratio were selected for each image quality metrics. The results are shown on Table 3 below.

Table 3. Loss Functions-SNR

Image Quality Metrics	Type	Signal to Noise
Density	Solid Area	The larger the better
Graininness	Solid Area	The smaller the better
Mottle	Solid Area	The smaller the better
Color Gamut	Solid Area	The larger the better
"Black Gamut" (unwanted)	Solid Area	The smaller the better
Gloss	Solid Area	Nominal the best
Line Width	Line	Nominal the best
Line Blur	Line	The smaller the better
Line Raggedness	Line	The smaller the better
Line Breaks	Line	The smaller the better
Line Density	Line	The larger the better
Line Fill	Line	The larger the better
Background	EP	The smaller the better
Q/M	EP	Nominal the best

Results and Discussion

In this study we have evaluated eight printers from different manufacturers. We chose a very popular printer, "Printer X" as a reference point. The recommended duty cycles, pages/min, and cartridge capacities of all of the printers are noted in Table 4.

Table 4. Evaluated Printers

Printer Code	Pages/Min	Toner Cartridge Capacity, pages	Monthly Duty Cycle, pages
Printer X	17	4,000	50,000
Printer A	21	12,000	120,000
Printer B	22	6,000	50,000
Printer C	20	5,000	60,000
Printer D	35	25,000	150,000
Printer E	26	5,000	60,000
Printer F	31	12,000	120,000
Printer G	17	4,000	50,000

Robustness Ranking

Based on the defined loss function of Table 3, S/N were calculated for each quality metrics, using the aggregated data generated over the three dew point conditions. We thus can compare each printer's performance for each quality metric. For example, Figures 1 and 2 compare the printers for L* graininess performance.

Further, we took advantage of S/N additivity to compile an overall robustness rating for each printer over the entire range of image quality metrics evaluated. Table 5 summarizes the results. To provide a better frame of reference, we also defined a relative ranking to Printer X. Thus it can be seen that Printer A is 26 dB better than reference Printer X, while Printer G is 62 dB worse.

The analysis above assumes equal contributions for all quality metrics. More sophisticated analysis would consider a weighted approach. For example, for photo-centric applications, gloss, granularity, and color gamut could be favorably weighted. CMY gloss could use a "larger the better" S/N, and K gloss a "smaller the better" S/N. All of these different data analysis schemes can be applied using the same raw data, at the time of the experiment or any other future time.

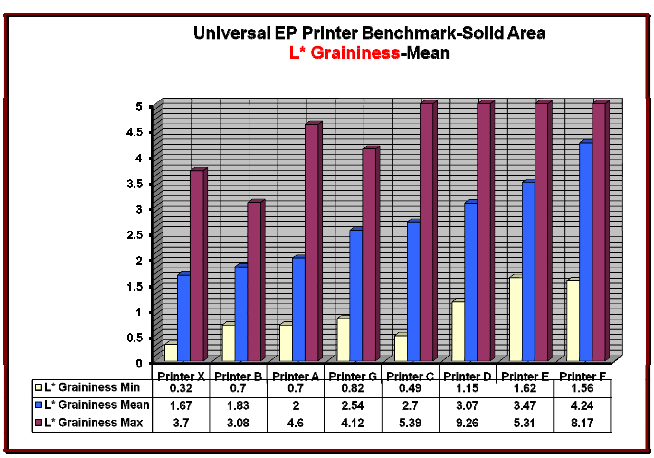


Figure 1. L Graininess Mean*

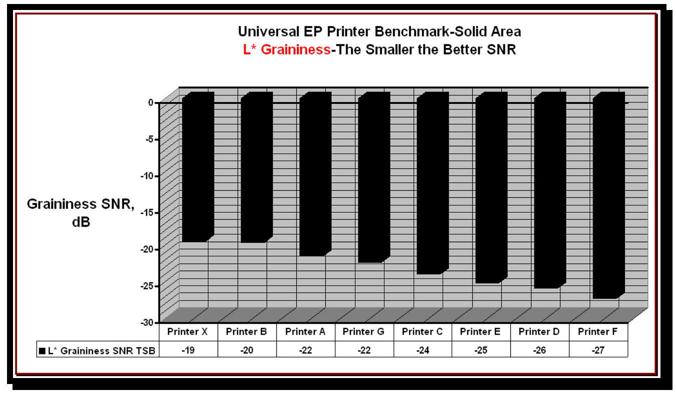


Figure 2. L Graininess S/N*

Table 5. Robustness Ranking

Universal Printer Benchmark S/N (dB) Ranking Summary									
Printer	Gamut Rank	Mottle Rank	Graniness Rank	Q/M Rank	Density Rank	Gloss Rank	Line Rank	Overall Rank	Printer X Rank
Printer A	238	-13	-23	17	1.6	20	-210	30	26
Printer B	224	-14	-25	14	0.4	18	-209	8	4
Printer X	233	-13	-19	15	2.6	16	-231	4	0
Printer C	247	-13	-26	14	1.8	20	-243	1	-3
Printer D	241	-14	-22	8	1.4	12	-231	-5	-9
Printer E	248	-14	-27	16	0.5	29	-236	-14	-18
Printer F	212	-13	-20	10	1.4	15	-250	-44	-48
Printer G	223	-14	-24	13	-0.9	15	-259	-58	-62

Toner Cartridge Benchmarking for Printer X

The Printer X is very popular with the cartridge remanufacturing industry. A quick Internet search leads to several suppliers of remanufactured cartridges for that printer. We chose two toner cartridge sets for benchmarking, using our test protocol. Toner-M set uses ground toner, while Toner-C set uses chemically prepared toner. Printer X also uses chemical toner. The graph of Figure 3 clearly shows the inferiority of the two remanufactured toner cartridges.

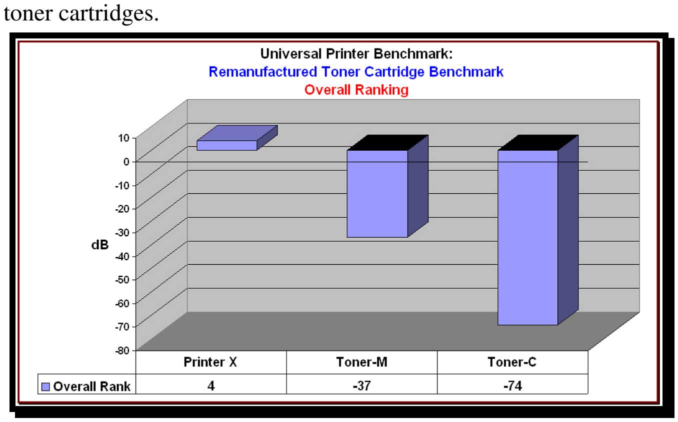


Figure 3. Remanufactured Toner Cartridges Benchmark

Summary and Conclusions

We have developed a universal benchmark test protocol for comprehensive and quantitative assessment of color printers. The test is consumable-centric, sized to the printer duty cycle, robustness-based, and expandable in scope. Although the actual examples are specifically for laser printers, the method is applicable to inkjet and other types of color printers.

The protocol can be used for multiple purposes: benchmarking the competition, improving existing product lines, or generating credible and reproducible data for product marketing.

Acknowledgments

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References

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Author Biography

Michel (Mike) Frantz Molaire is currently a senior research associate scientist at Eastman Kodak Company. He received his B.S. in chemistry, M.S. in chemical engineering, and M.B.A. from the University of Rochester. Mr. Molaire has been granted 49 U.S. patents, Kodak's C.E.K. Mees Award for excellence in scientific research and reporting. An inductee of Kodak's Distinguished Inventor's Gallery, and the African Scientific Institute Fellowship, he is a member of the American Chemical Society, the Federation of Societies for Coatings Technology, and the Society for Imaging Science & Technology He is currently serving as Programs Vice President, and President of the Rochester IS&T Chapter.