Image Quality Metrics for Printers/Plotters

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Abstract

Today, non-impact printers have become a common office peripheral. With this increase in market acceptance, the understanding of computer imaging has left the realm of black magic, known only by a select group of scientists and engineers, and entered into the mainstream of computer literacy.

Competitive bench marking articles in popular computer magazines no longer look at just the price of the printer, how clear the user manual describes using the software that comes with it and if the manufacturer's technical support department picks up the phone. They are beginning to look inside the device at the optical, mechanical and electronic precision as measured by output image quality.

Today, manufacturers are beginning to use sophisticated machine vision software technology to evaluate image quality and set the standards for their design and manufacturing operations. Their marketing organizations are using the same technology to perform competitive analysis.

Manufacturers of printers need to understand how this new technology is being applied to assure competitiveness, improve customer satisfaction and to be able to respond to the growing awareness and expectations in the marketplace regarding image quality standards.

This paper will present a series of specific metrics for quantifying image quality for non-impact printers. Specific metrics will include Color registration, Color consistency, MTF, resolution, Streak noise, Text quality, Motion quality, Linearity, Sharpness, Smearing effects, Dot quality and others. Discussion will also present methods by which manufactures have achieved a fully automatic image quality testing process. Case studies and examples of current installations at major printer manufacturers will be discussed.

Dot Quality Test

ImageXpert provides statistics for dots' area, gray average, axis ratio and roundness. As well as number of dots, area coverged and gray average.

Another case of poor dot quality is the image below. Instead of having a perfect chess image, some of the black squares are smaller and therefor do not touch their neighbor black squares in the corners.

Fit To Line Algorithm

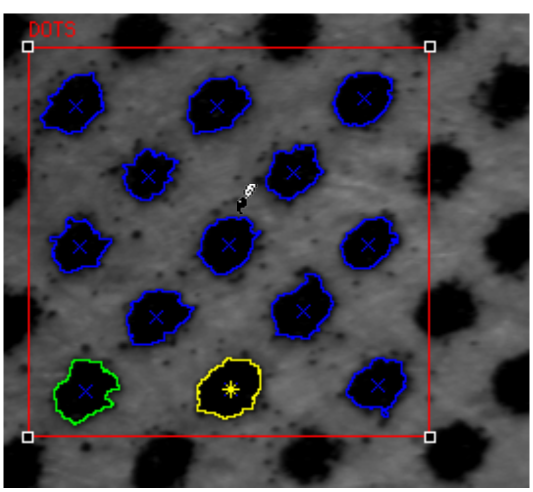
The feature fit to line was added to the Connectivity algorithm in ImageXpert to be able to calculate the displacement of the dots from the best fitted line. The algorithm detects the dots within the ROI and fits a line through the centers of these dots. The values obtained from this algorithm are: The line angle, line goodness (a criteria of how well the dots fit the line), average, standard deviation, minimum and maximum distances of the dots to the best fitted line.

Line Quality Test

Two of the most common problems of a printing device are known as "jitters" and "ripple".

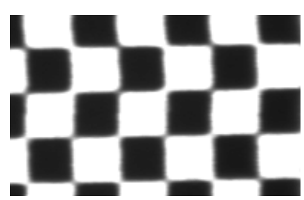
Three important measurable quantities is use to asses line print quality.

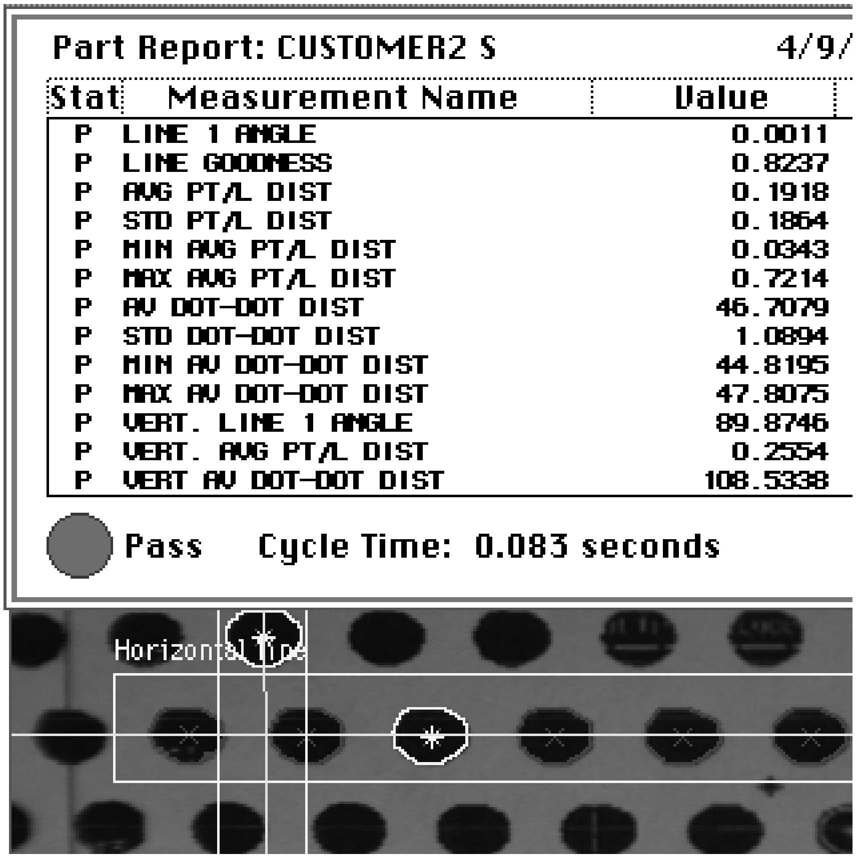
1. Stroke width
2. Raggedness - TEP (Tangential Edge Profile)
3. Sharpness -NEP (Normal Edge Profile)



Part Report: DOT QUALITY SQ

S	Measurement Name	Value
F	dot size stat	8.2872
F	dot size std.	1.9544
F	axis ratio av.	113.5978
F	axis ratio std.	1.0389

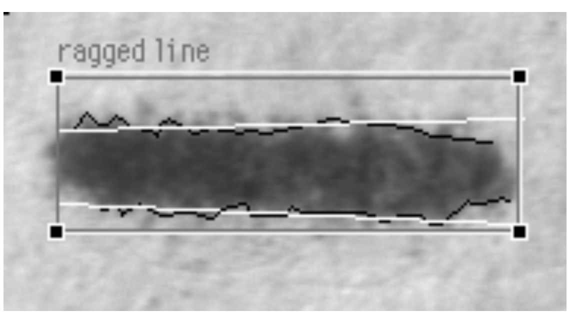


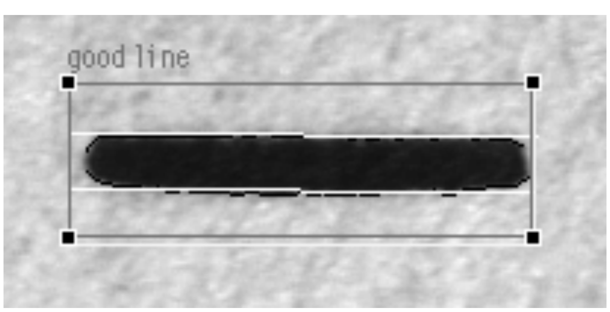


Part Report: CUSTOMER2 S 4/9/

Stat	Measurement Name	Value
P	LINE 1 ANGLE	0.0011
P	LINE GOODNESS	0.8237
P	AVG PT/L DIST	0.1918
P	STD PT/L DIST	0.1864
P	MIN AVG PT/L DIST	0.0343
P	MAX AVG PT/L DIST	0.7214
P	AV DOT-DOT DIST	46.7079
P	STD DOT-DOT DIST	1.0894
P	MIN AV DOT-DOT DIST	44.8195
P	MAX AV DOT-DOT DIST	47.8075
P	VERT. LINE 1 ANGLE	89.8746
P	VERT. AVG PT/L DIST	0.2554
P	VERT AV DOT-DOT DIST	108.5338

Pass Cycle Time: 0.083 seconds





Stroke width is the average width of the line. As the image gets blurred the size of the line width gets larger.

The raggedness (TEP) is defined as the displacement of its black-white boundary from its ideal base line.

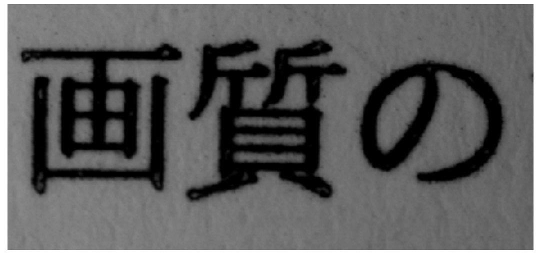
Text Quality Test

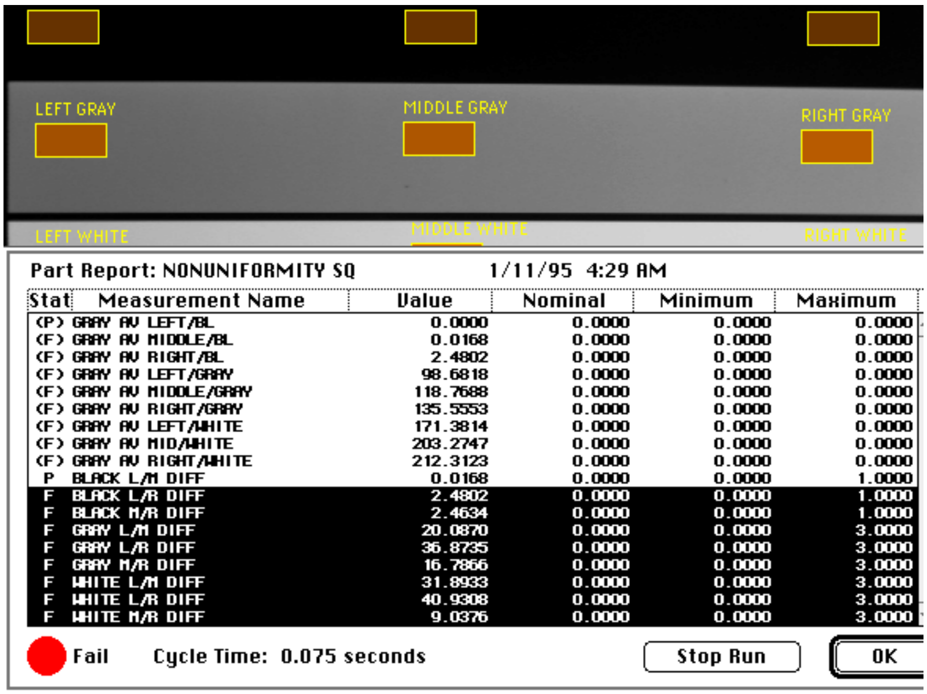
The text quality test text quality test provides information about touching, broken and smeared characters. In this test connectivity algorithm is used to detect the number of characters. A broken character or spill of toner will show additional number of parts in the measurement.

In the next example the test detects that the t and the y are touching. One character is missing from this measurement. This test can be done on any type of characters.

Uniformity Test

The largest contributor to non-uniformity in print quality is the ink. The uniformity specification will not be met if there is inconsistency in the amount of ink, paper quality variations.





Part Report: NONUNIFORMITY SQ 1/11/95 4:29 AM

Stat	Measurement Name	Value	Nominal	Minimum	Maximum
(P)	GRAY AV LEFT/BL	0.0000	0.0000	0.0000	0.0000
(F)	GRAY AV MIDDLE/BL	0.0168	0.0000	0.0000	0.0000
(F)	GRAY AV RIGHT/BL	2.4802	0.0000	0.0000	0.0000
(F)	GRAY AV LEFT/GRAY	98.6818	0.0000	0.0000	0.0000
(F)	GRAY AV MIDDLE/GRAY	118.7688	0.0000	0.0000	0.0000
(F)	GRAY AV RIGHT/GRAY	135.5553	0.0000	0.0000	0.0000
(F)	GRAY AV LEFT/WHITE	171.3814	0.0000	0.0000	0.0000
(F)	GRAY AV MID/WHITE	203.2747	0.0000	0.0000	0.0000
(F)	GRAY AV RIGHT/WHITE	212.3123	0.0000	0.0000	0.0000
P	BLACK L/M DIFF	0.0168	0.0000	0.0000	1.0000
F	BLACK L/R DIFF	2.4802	0.0000	0.0000	1.0000
F	BLACK M/R DIFF	2.4634	0.0000	0.0000	1.0000
F	GRAY L/M DIFF	20.0870	0.0000	0.0000	3.0000
F	GRAY L/R DIFF	36.8735	0.0000	0.0000	3.0000
F	GRAY M/R DIFF	16.7866	0.0000	0.0000	3.0000
F	WHITE L/M DIFF	31.8933	0.0000	0.0000	3.0000
F	WHITE L/R DIFF	40.9308	0.0000	0.0000	3.0000
F	WHITE M/R DIFF	9.0376	0.0000	0.0000	3.0000

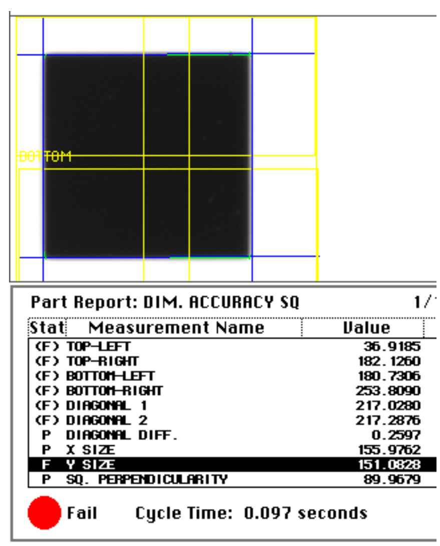
Fail Cycle Time: 0.075 seconds Stop Run OK

Dimensional Accuracy Test.

The dimensional accuracy test was designed to verify the dimensional accuracy of the printout. The dimensional accuracy test compares the length and width of the printed image (shown below) with the same features of the postscript files.

Color Registration Test

In an ideal printout all four separations (CYMK) of a line should collapse into one line. Any deviation of the line width indicates color misregistration. This test utilizes a line target and the line width is measured.



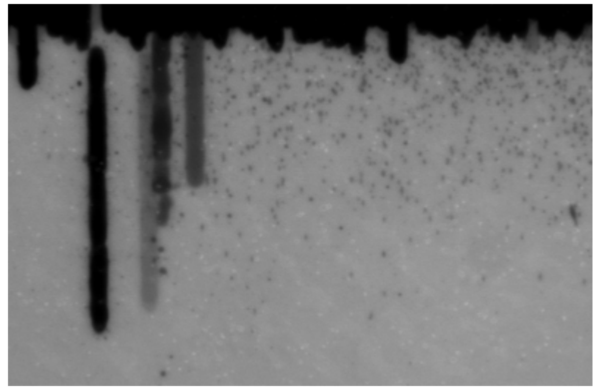
Part Report: DIM. ACCURACY SQ 1/

Stat	Measurement Name	Value
(F)	TOP-LEFT	36.9185
(F)	TOP-RIGHT	182.1260
(F)	BOTTOM-LEFT	180.7306
(F)	BOTTOM-RIGHT	253.8090
(F)	DIAGONAL 1	217.0280
(F)	DIAGONAL 2	217.2876
P	DIAGONAL DIFF.	0.2597
P	X SIZE	155.9762
F	Y SIZE	151.0828
P	SQ. PERPENDICULARITY	89.9679

Fail Cycle Time: 0.097 seconds

Color Consistency Test

Color devices typically have three intensity components (one for each of the primary colors red, blue and green) stored for each pixel in the image. The RGB colors may be combined to form any of the other colors in the spectrum simply by setting the appropriate intensity level for each color. While there are different ways to design a color device (printer, plotter etc.), manufacturers all need to measure the intensity consistency for each component for a given position on the target.



Part Report: COLOR CONSIST. SQ 1/11/95 4:48 AM

Stat	Measurement Name	Value	Nominal	Minimum	Maximum
F	RED COLOR 1 GRAY	27.5084	0.0000	0.0000	0.0000
F	RED COLOR 2 GRAY	242.6140	0.0000	0.0000	0.0000
F	RED COLOR 3 GRAY	31.8516	0.0000	0.0000	0.0000
F	RED COLOR 4 GRAY	37.1168	0.0000	0.0000	0.0000
F	RED COLOR 5 GRAY	32.6652	0.0000	0.0000	0.0000
F	RED COLOR 6 GRAY	27.5084	0.0000	0.0000	0.0000
F	GREEN COLOR 1 GRAY	27.6904	0.0000	0.0000	0.0000
F	GREEN COLOR 2 GRAY	254.5468	0.0000	0.0000	0.0000
F	GREEN COLOR 3 GRAY	20.2964	0.0000	0.0000	0.0000
F	GREEN COLOR 4 GRAY	45.9816	0.0000	0.0000	0.0000
F	GREEN COLOR 5 GRAY	226.0512	0.0000	0.0000	0.0000

The Color Consistency test measures the average gray level in the RGB planes for various colors on the target scan (illustrated below) and compares the results with the manufacturer's tolerances. This test assures the manufacturer that a series of devices will produce identical colors.

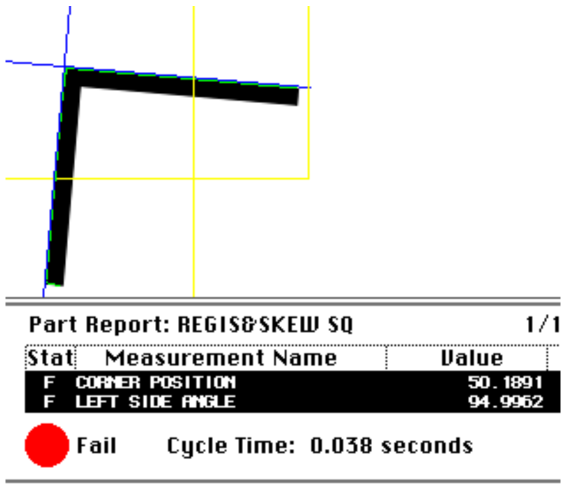
Resolution Test

The resolution test looks for an appropriate maximum resolved line pair per millimeter. Resolving a target requires that the lines both in the horizontal and the vertical direction satisfy the following conditions:

1) The lines are not broken.
2) The lines are not touching each other.
3) The length of the lines won't be shorter than 10% of the target lines.

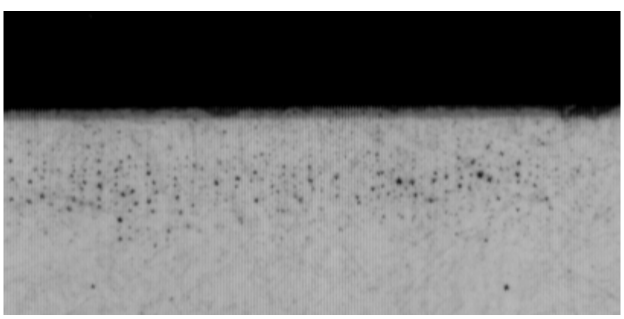
Registration & Skew Test

Skew is the amount of rotation of the target axes relative to the image axes. A device with a skew problem with generate an image that appears to be rotated from its desired orientation. Registration is the collocation of the origin of the target with that of the image. The resulting image from a device with a registration problem is one that appears to be displaced or cropped by a constant amount in X-Y space.



Smear Test

The dots below the solid lines are the results of toner spill over. This test measure the amount of spill over by measuring the area of the dots verse the distance from the solid line.

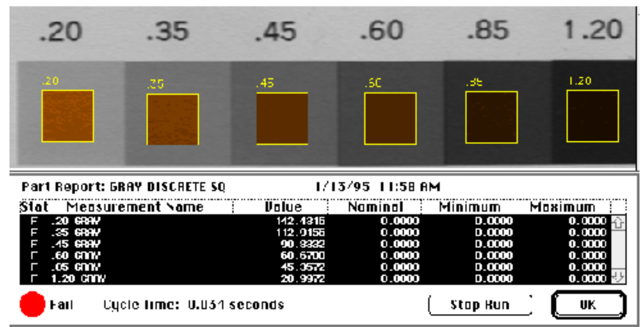


Sharpness Test/Rise Time

Rise time is a measure of the image sharpness. The test produces information on the transition area between black to white. The test related to this issue measures the average number of pixels in the transition from dark to light pixels. In a blurred image the transition occurs over a large number of pixels, whereas in a sharp image the number of pixels in the transition region is minimized.

Linearity Test

The linearity test was designed to measure the device output for known reflectance step tablets (i.e. IEEE 167). This test allows the user to measure how linear is the output of the device and what is the noise level in each one of the gray tablets. This test uses any number of reflectance tablets with incremental change of reflectance from black to white. The gray level and the standard deviation of each tablet is measured.



Criteria for Measurement

Since any sprinters is a complex electro/optical/mechanical device, measuring its performance is a complex task requiring a series of discrete analyses focusing on its specific components. Each of these components can affect the quality of the image in a different way, so each must be measured separately in order for an objective analysis to be made.

The following sections describe each Image Quality test and its associated test print.

Impact on the Market

With increased use of automated image quality analysis tools built on these criteria, the growing population of scanner and cameras buyers can be assured that the quality of their output will be more consistent and within specification.

At the end user level, they can implement quality control procedures to monitor the performance of their scanner operations. At the field service level, they can reduce the time required to diagnose malfunctions and other problems by analyzing the image output. Using a modem, the test image may be transmitted to the service office for analysis so that the technician need not be on site.