

Image Quality Tests For Printers

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Today, both impact and non-impact printers have become common computer peripherals, for the business and consumer market. 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 benchmarking articles in popular computer magazines no longer compare just the price of the printer, the clarity of the user manual, and the manufacturers' technical support department responsiveness. They are beginning to look inside the device at the optical, mechanical and electronic precision as measured by output image quality.

Printer manufacturers are starting to investigate the use of sophisticated machine vision software technology to evaluate image quality and set the standards for their design and manufacturing operations. Marketing organizations are using the same technology to perform competitive analysis. The manufacturers are beginning to use machine-vision-based systems to evaluate product quality and provide the feedback necessary to set quality-control standards.

When performed manually, print quality inspection is time-consuming, labor-intensive, and stressful, not to mention subjective and prone to dependence on many variables. Objects as small as 10 microns must be measured at different locations on a document. At the same time, the dimensions of the entire document must be checked. All this requires calibrated microscopes and translation stages, with accompanying operator training and gage studies.

According to Nyquist theory, the sampling frequency of the imaging system for ispection should be at least twice the frequency of the features being examined. If a printer produces 600-dpi images, the system must resolve at least 1200 dots per inch. The solution is to use large area-array charge-coupled device (CCD) cameras to acquire, at high resolution, the few regions of interest required for image quality analysis. Since only 15% of the print area needs to be digitized for such analysis, print-inspection systems are more effectively built around motion-based systems using these large format CCD cameras. Such systems acquire images by moving an image positioned on an x-y table under the camera. By doing so, the amount of storage required for image analysis is minimized, the problems of operator-based inspection are alleviated, and there is a faster, more cost-effective means of print analysis.

An I/O interface card communicates with external devices to allow incorporation of devices such as document feeders. A motion controller connected to the RS232 serial port allows the x-y table to be controlled at different motion resolutions and for different image sizes. Two different cameras supporting two different lens types are used. The first, with a field of view (FOV) of 1 to 6 mm, is used to measure dot quality, dot placement, or color registration. The other, with a FOV of 10 to 30 mm, measures print dimension and color consistency. Each lens has a focusing mechanism and iris. A high-fre-quency fluorescent lens and a halogen lamp with fiberoptic light guide illuminate the document under inspection.

In operation, the system automates the analysis of print quality on non-standard test targets. These targets provide test patterns from which dot quality, streak analysis, line quality, sharpness, resolution and more can be made. As a menu-driven program, the system offers image processing, analysis data collection, and reporting tools; results are reported in a spreadsheet that can be compared to user-defined pass-fail tolerances or used for statistical analysis.

Automatic and Interactive Analysis

Two distinct methods are used to analyze an image. Interactive analysis provides the operator with graphical interface tools to manually interact with the image during analysis. Automatic analysis creates a macro-like sequence of image-analysis steps that can be repeated with a single keystroke. A sequence of instructions can be built to enhance feature appearance, count objects, determine density, shape size position and movement, perform object feature extraction, and conduct textural analysis.

Algorithms include area, connectivity analysis, edge analysis, gray-scale analysis, vector analysis, Hough transform, morphology, correlation, enhancement, OCR and image arithmetic. All of these algorithms operate within a user-defined region of interest (ROI) that can be as small as a single pixel or as large as the whole image.

A task editor incorporates motion capability into the system. This allows sequences of operations (task lists) to be created via pull-down menus. Using the editor, a list can be constructed that includes motion commands, vision commands, input/output (I/O) commands, and flow control (for loops and conditionals). To construct imaging applications, these inspection sequences can be trained and run automatically.

Calibrated Motion Measurements

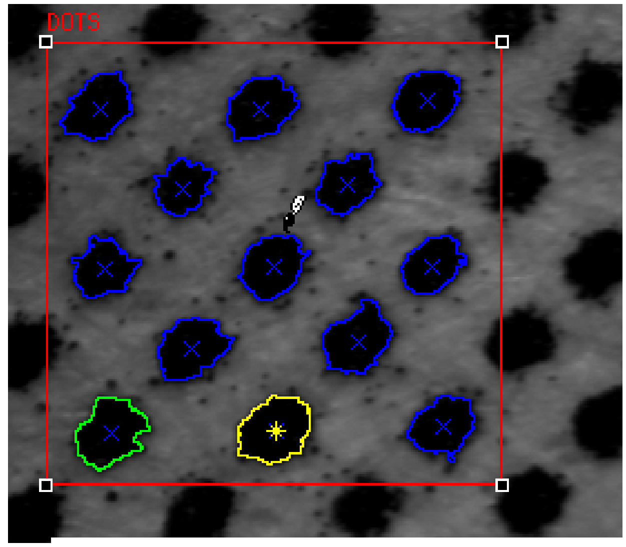
When dimensional-accuracy measurement of a large format-target is required, extended FOV has to be used. In such cases, the four corners of the target are not within one FOV, and the x-y table must be moved to each corner of the image where separate images are captured and characterized, and the distances between corners are measured based on the the x-y table travel.

In print-inspection applications, the field of view of the camera could be as small as 1 mm. This translates to about 2 microns per camera pixel. If a page is not placed properly on the x-y table, the feature to be measured will not be within the field of view. To compensate for this misplacement, dynamic image location accommodates image misplacement.

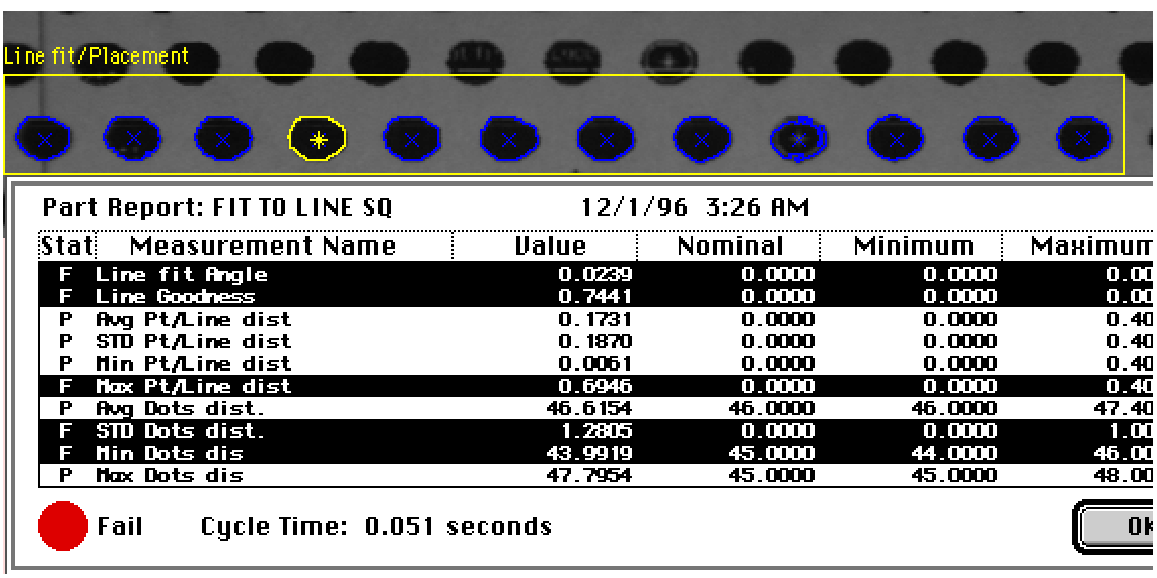
Testing Image Quality

Image quality on printed material can be measured by studying various aspects of the printed image. These include dot and line quality, uniformity, and sharpness, color registration, resolution, and others.

Dot quality can be assessed by measuring all of dots within a specific field of view, and providing analysis of the individual characteristics as well as statistical results for the total. A decrease in the number of dots in a given image can occur when some dots are significantly undersize or missing, or multiple oversize dots collapse to create a larger dot. Increase in the number of dots can occur when large satellites appear. To analyze print dots, ImageXpert provides algorithms for area, gray average, axis ratio, and roundness statistics. These results can be output to analysis packages for further examination.



Drop placement error is the result of print-head performance. It can result in misplaced or missing drops. The missing drop phenomenon can occur either because some dots are not printed or because two or more misplaced dots collapse to create larger dots. This is measured by counting the number of dots detected within the FOV. The misplaced dots are detected using the Fit to Line test. For example: 1) the horizontal distance between the dots can vary (center to center); 2) the dots themselves, instead of being placed on a straight line, deviate from it. If one of the dots is missing it will obviously show in the horizontal distance between the dots.



Part Report: FIT TO LINE SQ 12/1/96 3:26 AM

Stat	Measurement Name	Value	Nominal	Minimum	Maximum
F	Line fit Angle	0.0239	0.0000	0.0000	0.00
F	Line Goodness	0.7441	0.0000	0.0000	0.00
P	Avg Pt/Line dist	0.1731	0.0000	0.0000	0.40
P	STD Pt/Line dist	0.1870	0.0000	0.0000	0.40
P	Min Pt/Line dist	0.0061	0.0000	0.0000	0.40
F	Max Pt/Line dist	0.6946	0.0000	0.0000	0.40
P	Avg Dots dist.	46.6154	46.0000	46.0000	47.40
F	STD Dots dist.	1.2805	0.0000	0.0000	1.00
F	Min Dots dis	43.9919	45.0000	44.0000	46.00
P	Max Dots dis	47.7954	45.0000	45.0000	48.00

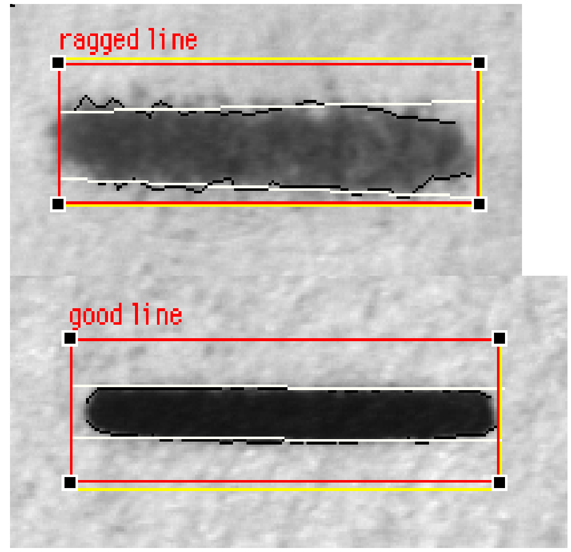
The algorithm detects the dots within the ROI and fits a line through the centroids of these dots. The values obtained from this algorithm include: line angle, line goodness (a measure of how well the dots fit the line), average, standard deviation, minimum and maximum for the distances of the dots from the best fitted line; as well as average, standard deviation, minimum and maximum center to center distances.

In line quality, two of the most common problems of a printing device are known as "jitter" and "ripple". In many cases absorption of ink dye by the paper causes feathering and spreading of the line boundary. Three important measurable quantities are used to assess line print quality:

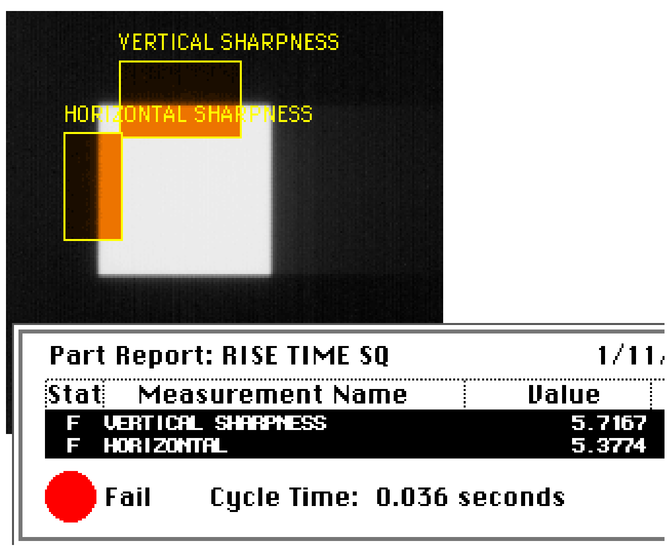
1) Stroke width;
2) Sharpness—NEP (Normal Edge Profile);
3) Raggedness—TEP (Tangential Edge Profile).

Stroke width is the average width of the line. As the image gets blurred, the width of the line increases. Sharpness (NEP) is defined as the optical reflectance factor gradient at any position along and normal to the image plane. The NEP is a measure of the width of the transition from the light to dark area. Large NEP's tend to make edges appear blurred. An ideal NEP would be a step function with zero width.

The raggedness (TEP) is defined as the displacement of its black-white boundary from the ideal edge. It describes how ragged the edge appears. This value is calculated as the mean square deviation derived from the average deviation in pixels of the edge points (the points where the transition occurred) from the best fit line through the edge points. An ideal TEP would be a straight line having deviation equal to zero. Ragged edges are the results of dot placement error (machine phase) combined with ink interactions with the paper (substrate phase).



The largest contributor to nonuniformity is ink quality. If there is any inconsistency in the amount of ink or paper quality, printer-uniformity specifications will not be met. To test for this, ImageXpert compares the gray-level average in any number of locations in the horizontal direction of a printed target image. The test calculates the differences in the gray level for any two regions and compares the result with tolerances that are user-specified.



Summary

Since any printer is a complex electronic/optical/mechanical device, measuring its performance is a complex task requiring a series of discrete analyses focusing on each specific component. 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. With the use of automated image quality analysis tools built on these criteria, ImageXpert assures manufacturers that the quality of their product output will be consistent and within specification.

It is also valuable to the manufacturers for lowering costs by increasing the yield through statistical process control (SPC). The availability of not only the yield data, but the reason each discrepant unit failed, would allow the real-time control of the manufacturing process to maximize the yield while minimizing the cost of quality assurance. In production, the limits on acceptable test results can be established to provide constant feedback on product variability, and specific criteria can be used to isolate sources of noncompliance. Development efforts on new and improved products and performance can benefit through the ability to design multi-variable experiments and independently characterize the effects of each parameter on image quality.

With increased use of automated image-quality-analysis tools, printer manufacturers can insure more consistent output quality. And, they can implement quality-control procedures to monitor the performance of printer manufacturing. Manufacturers of printers need to understand how this new technology can be 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.