

Image Quality Testing on the Production Line

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Abstract

Eastman Kodak Company is using a scanner-based image quality measurement system to perform production line testing of the image quality of a high-quality thermal media based imaging system. Automating this process has led to increased throughput, has guaranteed uniformity in measurement methods on multiple branches of the production line, and has transferred subjective evaluations into parametric data for use in SPC control/failure correlation analysis.

Traditional production line assessment methods relied on using handheld instrumentation or using visual comparisons. These methods are inherently variable and often quite subjective. Objective, quantitative analysis provides repeatable data that can be used to track build performance, assess population quality, and track failure modes. Automation increases throughput and decreases the need for operator intervention.

This paper will present the measurement system and methods that are being used in a production environment to automatically verify the output image quality of thermally based digitally created images.

Introduction

Modern printer production environments require the use of automated image quality analysis. Traditional methods of visual inspection and comparison rely too heavily on subjective judgments, are highly variable, and are tedious and time consuming. Timeliness is a critical factor since maintaining high throughput while performing high quality quantitative analysis is of critical importance in production environments. In addition, the data resulting from traditional assessment methods does not always lend itself to numerical feedback and control methods such as SPC and failure analysis.

Goal

The goal for the production of this product was to identify and implement an automated solution for image quality measurement. The solution needed to allow sufficient autonomy for the user in integrating new tests, modifying old tests and defining tolerances, without compromising customer service and support for system installation, integration, training and maintenance. In order to meet these requirements, Kodak chose ImageXaminer™, a scanner-based image quality measurement system developed and distributed by KDY Incorporated of Nashua, New Hampshire. ImageXaminer has been integrated into the production line of the Kodak Professional 8660 thermal printer.

Critical Parameters

In order to reach the point of production, the product has obviously reached a certain level of maturity. The product design has been developed and refined to meet a certain set of performance criteria including several image quality performance specifications. During development, a multitude of image quality attributes was measured to ensure design validity. Inter-relationships between certain design parameters and image quality have been well established and the broad set of image quality attributes necessarily monitored during system design have been boiled down to a smaller subset, the few key attributes (or critical parameters) that guarantee overall image quality of the system.

In the case of this specific product, a narrow set of macroscopic image quality attributes including banding, image placement (image border), color registration (image plane registration), light printing, and parasitic resistance are sufficient to describe performance of each subsystem within the printer and thus assure a high quality product.

Measurement System

Scanner

A scanner was chosen as the input device for the automated image quality measurement system because it is cost effective and all of the image quality attributes that require verification are macroscopic with the exception of color plane registration. The scanner is a very effective and appropriate input device for quantifying many macroscopic image quality attributes.

Scanner Calibration

In order to guarantee the quality of the analysis, the image quality of the scanner itself is pre-qualified prior to performing print quality analysis. In addition, the scanner automatically performs a self-calibration at the start of each scan that uses an integrated test target to evaluate and compensate for any illumination non-uniformities across the lamp.

Test Target

A Kodak proprietary test target was developed to specifically highlight the attributes being measured. This target is very specific to thermal printing. The test image is designed with features that stress the printing system to magnify the effects of artifacts relative to the typical set of images that customers would print. Other features in the test image are designed to merely make it easier to measure inherent performance of the printing system.

Measurement Method

Each print sample is placed on the platen and scanned in reflective mode. For data processing efficiency, every feature of the test target should be measured at its own optimal scanning resolution. Some system performance measures, like Gray Scale Calibration accuracy only need low resolution information, but others like Image Plane Mis-Registration require high-resolution data. We save time during scanning by acquiring this entire test image at 600 dpi because multiple scans of an image at different resolutions would require the scanner mechanism to make many traverses of the platen. This scanning resolution is a compromise that yields more data than really necessary for many attributes, but meets the minimum needs of all measures. Some targets are acquired most efficiently with multiple, small area scans. The flexibility to scan various sections of a test target at different resolutions, with different scanning modes (color or gray scale) can decrease the acquisition time for some images.

Each scanned section of the image is then evaluated automatically. In cases where post-processing is necessary, (as in those cases where digital count values are translated into Status-A density values) data is exported to Lab View™.

Digital Count to Density Conversion

In order to build the equation relating scanner digital counts to density values, an X-Rite™ Model 310 Densitometer is used to make multiple density measurements of each patch of a calibration target, which is printed on the same thermal media as the print samples, which are evaluated during production. Regression is performed on the density and intensity data sets to determine the mathematical relationship between the two. The coefficients are stored in the database where all data is collected. Gray-value data from the scanner is passed through the regression equation to convert it to equivalent Status-A density for tracking and reporting purposes.

Image Quality Attributes

Periodic Banding

Periodic Banding is patterns of non-uniformity (across the image) that repeat down the page in the process direction. Banding manifests itself at frequencies associated with gear tooth count, roller sizes, and other mechanisms that inflict periodic perturbations in the paper velocity during printing.

Periodic banding is evaluated by taking the FFT of the gray profile of a gray band that runs the length of the page. The magnitudes of the various periodic components are evaluated against a specification curve for pass/fail determination.

Drag Lines

Drag Lines are spurious lines in the image that sometimes appear just after printing a high density area as shown in Figure 1. The artifact is related to temporary changes in the heat transfer efficiency of the print head's heater elements for various reasons.

Drag Lines are evaluated by quantifying bands in the background area following a high density printed area.

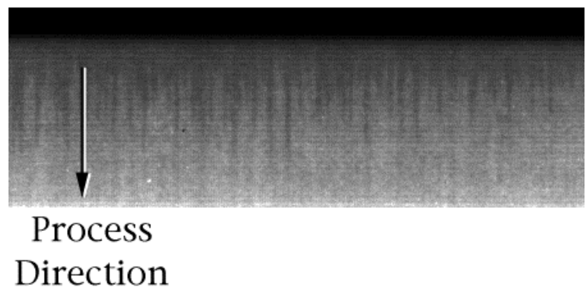

Figure 1. Drag Lines

Image Border

Image Borders are measured at the top of the print and at the left edge when the top of page is defined as the region where the first lines are printed.

Border locations are measured from the edge of the cut sheet to a set of linear fiducials placed parallel to the edges of the paper.

Image Plane Misregistration

We define Misregistration as the error in placement of the magenta and cyan image planes relative to the Yellow image plane. Misregistration is reported for both process and cross-process directions for magenta and cyan and is measured in all four corners of the image.

Because the scanner is a relatively low-resolution image input device, a robust measurement method was chosen to minimize potential resolution-induced errors. The centroids (geometric centers) of a series of single color dots are determined using ImageXaminer's connectivity algorithm. Connectivity can measure the centroid of a dot with subpixel accuracy. The distances between these centroids are used to quantify the registration of the color planes relative to one another.

Light Printing

Light printing is the loss of, or non-uniformity in image density associated with mechanical effects. Poor pressure uniformity or inadequate pressure in the nip between the printhead and the thermal media causes light printing.

In order to quantify light printing a low-density gray field that extends most of the length of the image is measured on each side of the print. The density values themselves and the variability between the left side of the print versus the right side of the print are used as the basis for determining the existence and magnitude of the light printing artifact.

Parasitic Resistance

Parasitic Resistance is an image artifact induced by variable electrical resistance within the power supply, the printhead, and the cabling between the two components. The uncompensated artifact would appear as a plus-density error in a printed image region that lies next to (cross process direction) a low density printed area. Over-compensation would result in the opposite defect: the density in a printed region next to a low density area would be lower than expected.

Parasitic resistance is measured by calculating the density difference between the intended density and the actual density in a printed area located next to a low density printed area.

Statistical Process Control

Measurement results from the ImageXaminer system are written in tab-delimited format to network files by each audit station as the analysis is completed. A Lab View program looks for those data files and grabs them once all appropriate files are present. The Lab View application extracts certain data from the text files and adds records to MS Access™ database tables. The ImageXaminer operator gets feedback through a Lab View interface (on a separate PC) where Pass/Fail criteria are displayed. Buttons on this screen take the operator to a control chart selection where she can display control charts for any selected Image Quality measure.

Lab View queries the database at the operator's request and provides control charts for the selected measure. A Quality Engineer manages the display of control charts through a table in the database that defines preferred chart type, limits, and other options for each field in the database table. For example, image plane registration is monitored with a control chart for individuals, as seen in Fig. 2. Parasitic Resistance, on the other hand, is monitored with an Xbar-R chart. Registration can fail in a printer caused by assembly errors, where parasitic resistance is compensated with an internal algorithm and individualized scaling factors that are generated in another external tool. Monitoring the parasitic performance in a 'process' mode helps us to track the tool's ability to perform the correction process, where Registration really generates Pass/Fail criteria for each printer.

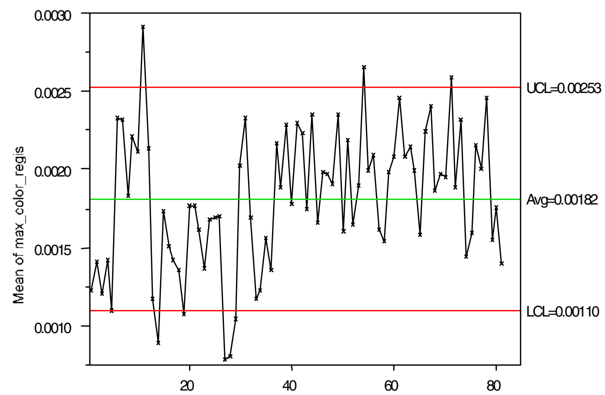

Figure 2. Registration control chart

Conclusion

Seamless integration between the ImageXaminer automated image quality measurement system and a PC based Lab View and MS Access has enabled production-line inspection, tracking and reporting of printer image quality for the Kodak Professional 8660 thermal printer. The data is being used successfully for product performance verification, failure analysis and determination of appropriate corrective action.

Biography

Randy joined Kodak in 1985 after serving 10 years in Air Force photo labs as a photoprocessing technician and quality assurance supervisor. At Kodak he has worked exclusively with digital imaging systems. Randy received his Bachelor of Science in Applied Statistics from RIT in 1994 and currently leads a system engineering group supporting development of new digital thermal printers.

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