The Role of Quantitative Data in Graphic Arts Production Facilities

Yair Kipman
ImageXpert, Inc
Nashua, New Hampshire, USA

Abstract

Statistical process control, the creation of internal standards, and equipment performance tracking are becoming increasingly important to commercial digital printing companies. Traditional subjective methods are commonly used for adjustment of color registration, dot gain and color balance. Unfortunately these subjective techniques are inherently variable between operators and do not lend themselves to data tracking and process control schema.

In this paper, we will be discussing the expanding role of quantitative image analysis techniques and instrumentation in evolving digital printing environments.

Introduction

In almost any circumstance where visual methods are currently being used to evaluate image quality in production printing, instrumented measurement methods can either replace or augment results adding objective legitimacy, traceablity and archival validity. Often, increased efficiency is an added benefit.

Although the processes presented in this paper may be well known, the potential role (and benefits) of introducing quantitative data at various points in the process may not have been fully considered.

History

Densitometers, colorimeters and magnifying loupes have long been standard equipment in production print houses. However, the use of additional equipment for image quality assessment and control is just now becoming more common in response to the changing role of production print facilities.

Production printing used to be defined almost exclusively by large-scale press runs. The unavoidable waste produced during press set-up was factored into the total cost of the project and was amortized in price per piece. However, as the paradigm of print houses has been shifting to support shorter print runs, print-on-demand, and variable content printing, waste levels have had to be reduced to support continued patronage by an increasingly educated customer base with a wider variety of vendor options to choose from to fulfill their needs. As a result, the goal of waste reduction, along with increased use of pre-press proofing and the need for continuous printer control and characterization have led to new opportunities for image quality measurement equipment manufacturers.

Applications

Pre-Press Proofing

The overall technical objective of pre-press proofing is to achieve the closest match possible between the output of the proofing device and the intended output of a specific printing process.

Proofing is an invaluable method of communicating with customers prior to production. For example, the specific purpose of contract proofs is to establish an agreed upon production goal between the printer and the customer.

Proofing is also an economical way to communicate internally during press set-up. For example, the bluelines used to verify bleeds and trim, work in process proofing (WIP), and imposition proofs allow print houses to confirm details of the job prior to costly press makeready.

Ensuring proof quality requires knowledge about the proofer's responses compared with response of the press or production printer. Important attributes include color fidelity, dot structure and tone reproduction.

Measuring these attributes and others like them allows for objective and accurate correction of tone reproduction curves, modification or selection of screening options and provides valid repeatable input into color management software. Quantitative data can assist in determining the relationship between the performance of the proofing device and the performance of the press or production print engine. Once the transfer curves are developed, modifications in the proofer can be made to better model the intended output.

Traditional adjustment of proofing device output qualities relied on trial and error iterations based largely on visual assessments. These methods can be lengthy and wasteful. Time and materials can be saved by applying methods that are scientifically based and observer-independent.

Computer to Plate

Computer to plate technology is becoming more and more widespread in print production facilities. With this new technology have come additional concerns over plate quality and materials.

Image quality measurement equipment can be used to qualify materials and evaluate plate quality prior to print runs. The process of verifying correct exposure and magnification, inspecting for the presence of defects and determining whether directionality effects are within spec limits currently relies on visual evaluation methods. Measuring plates with objective instrumentation provides consistency in monitoring methods and can enhance the reliability of inherently variable subjective judgements by providing supporting data for tracking performance.

Figure 1 shows a high-magnification view of a portion of a plate. This starburst pattern is typically used to determine system resolution and directionality.

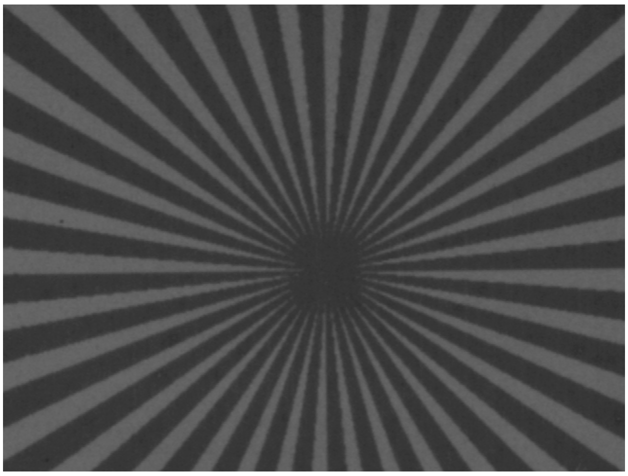

Figure 1. High magnification image of a test target on an aluminum-based plate

In addition to qualifying the CTP methods and materials, quantitative measurement equipment can be used to evaluate plate stability during longer runs where warping and stretching may occur in polymer-based plates. A camera could be placed such that the position of the plate edge is monitored or image capture could be synchronized with the system to capture images of a specific feature on the plate. If the edge or feature moves beyond a pre-set tolerance limit, the press operator would be notified. Pre-emptive analysis can help production facilities avoid the costs of unacceptable output quality.

Qualify Compatibility of Materials

Quantitative image quality analysis can aid in verification of compatibility between inks and specific substrates. Improper matching of ink and substrate can result in poor image quality and image stability. The following figures (figures 2a and 2b) show a high magnification view of the same image printed using the same ink on the same printer—but on different substrates.

Clearly, the choice of substrate has a large impact on the output quality. Not only do ink and paper interactions impact dot quality and other attributes of image microstructure, but the same interactions can impact more macroscopic qualities such as color gamut, stability and tone reproduction as well.

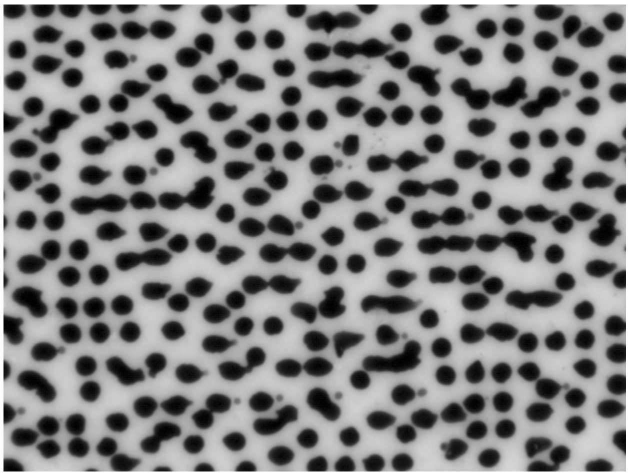

Figure 2a. High magnification image of a halftone printed on a glossy substrate

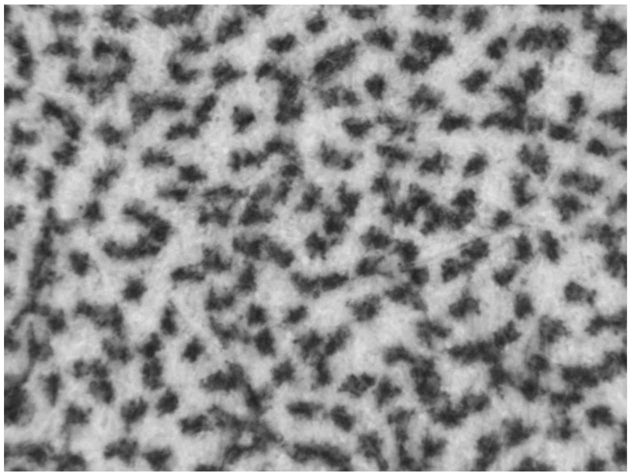

Figure 2b. High magnification image of the same halftone printed on a plain, uncoated substrate

Press and Proofing Device Fingerprinting

In order to improve efficiency by decreasing the down time between press runs, many production facilities fingerprint their presses, production printers and proofers to achieve an understanding of the inherent dot gain and tone reproduction characteristics for specific substrates. Visual characterization alone does not have sufficient historical relevance. Only repeatable, quantitative data can be used as truly reliable archival data. Measurement equipment can be used to assist in the verification process during the proofing process and press set-up by enabling objective comparisons between intended performance and actual output quality.

Consistency In Distributed Printing Output Quality and Print-On-Demand (POD)

Distributed printing requires consistency across several print engines. Although each engine might be individually well behaved, the process of tuning the engines to perform in concert can be quite challenging. Analytical evaluation of print engine performance can provide a base-line for each print engine, and can provide the objective data necessary for successful engine modification.

Print on demand requires that production houses maintain consistency in press and printer performance over time.

Printer Manufacturers

Printer manufacturers themselves already benefit from the widespread use of analytic equipment to qualify engines during development and production. Consistent use of image quality measurement equipment from the development phase through production to the field can aid in performance tracking, verification, and failure analysis.

Different printer technologies require different image quality measurements. The measurement of jet performance and inter-color bleed, for example, does not make sense on an electrophotographic (EP) printer, but they are critical features of inkjet printer performance. Fix (toner or wax adhesion), on the other hand, is often a critical concern on EP printers and on phase-change inkjet systems, but is irrelevant for liquid inkjet printing systems.

Ink and Paper Manufacturers

As in the case of printer manufacturers, manufacturers of both marking and receiving media have benefited from integrating quantitative analysis into their development and production processes.

Raw Stock Analysis

Many raw stock characteristics impact image quality. Some characteristics require high magnification; others can be quantified using low magnification. Paper formation and coating uniformity (gloss, bands, streaks, and scratches) analysis requires a macroscopic, low magnification measurement approach. On the other hand, analysis of fiber orientation and dirt count requires much higher magnification image capture capabilities. In all high magnification paper analysis, a statistical sampling must be applied in order to determine the true characteristics of a sample. One single measurement may or may not be indicative of the overall performance of a sample.

Printability

Printability measures how well a specific medium prints on a specific printer. In order to measure printability, an analytical test target or set of test targets are printed with the marking medium or on the receiving medium of interest and then the results are evaluated. If a comparison of the printability performance of various media is desired, it is critical that all other system variables remain constant. For example, if the performance of the receiving medium is being characterized, the marking media should be standardized, the same printer and printer settings should be used, and the same front-end settings should be applied. In order to isolate the contribution to overall image quality by the marking or receiving medium, all other aspects of the imaging system should remain constant.

Measurements

Color Quality and Control

Use of color measurement equipment has long been standard practice in most production printing environments.

The color performance of an imaging system can be measured with a spectrophotometer or colorimeter to assess, characterize, or control the quality of the hard-copy output. Many production houses use hand-held instruments to determine color quality. Others use automated color measurement devices. Many instruments offer flexibility in color reporting so that color measurements can be performed using any of a variety of user selectable observer angle/illuminant combinations and the results can be reported in a number of color spaces (such as CIELab, CIELuv, and HSV).

Color consistency is also a concern in all print jobs and is of special concern in distributed printing where different technologies may be blended to complete a single job. Color consistency tests the color uniformity across a single print, between prints or between printers.

Color Registration

In an ideal four-color print, all four separations (CYMK) of a composite line should be exactly superimposed. Measuring the distances of each of the single-primary lines to a black-only line can aid in determining which plane (if any) is mis-registered.

The color registration test can be performed in both the horizontal and vertical directions. In fact, the measurement should be repeated in different orientations to determine which color plane is mis-registered and in which directions. It should also be repeated at different locations on the target to provide more information about the uniformity of the mis-registration.

Screen Angles

Verification of screen angles is often achieved using a screen finder tool. This visual method provides feedback to the operators, but it relies on somewhat subjective analysis. Instrumented analysis of screening angles can simplify and objectify this measurement process. Making objective measurements increases repeatability and reliability and can make system adjustments more accurate.

Resolution

The quantification of resolution measures a printer's ability to print high frequency line patterns. Testing resolution produces information about the detectability of the transition area between adjacent black lines. Images from a printer exhibiting good resolution will have clearly discernible lines. A system with lower resolution will have images where the transition area is not well defined and in some cases is somewhat or mostly filled in. The degradation of resolution can be a result of different mechanisms including wicking, scatter and too much line growth. Quantifying resolution gives a good indication of how well a particular system will be able to legibly represent high frequency details in an image.

Dot Quality

As with most image quality attributes, dot quality can be impacted by the printer mechanism, the characteristics of the ink or other marking medium, and the properties of the substrate. Unevenness in dot placement, formation, or density can result in degraded image quality. Dots that have a significant amount of variation in density, shape, size or placement (in the case of amplitude modulated screens) cause halftoned areas to appear mottled or grainy.

Line Quality

The following attributes are among the metrics that can be used to assess line quality:

- Stroke width
- Raggedness - TEP (Tangential Edge Profile)
- Sharpness -NEP (Normal Edge Profile)

Stroke Width

Stroke width is a measurement of the average width of the line. If an image is blurred, the apparent width of the line increases in size. A line with varying stroke width will appear to have varying density.

Raggedness

Raggedness (tangential edge profile or TEP) is a measure of the displacement of the actual line edge from the ideal boundary line. The ideal boundary is determined by calculating the best-fit line through the edge points. The mean distance of each of the actual edge points from that best fit line is often used to quantify raggedness.

Raggedness is often used to quantify the magnitude of wicking in ink-based imaging systems. Wicking is often seen along the edges of lines and solid areas as a result of the interaction between the ink and the substrate. Specifically, wicking is a result of ink flow along the paper fibers. As a result, wicking is often directional, with a stronger component along the axis of the primary fiber orientation. The following figure (figure 3) shows two lines from different imaging systems. One line is exhibiting wicking, and the other line is not.

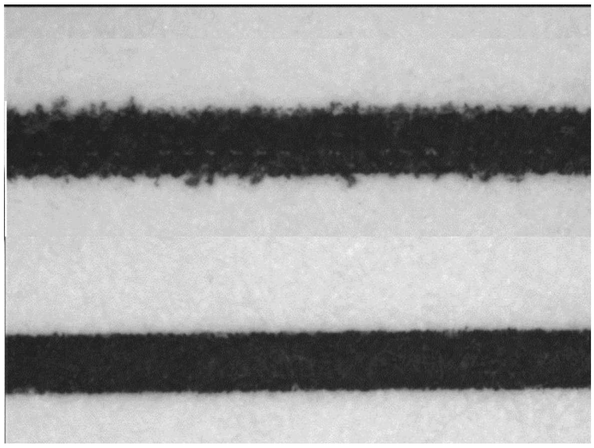

Figure 3. Example of wicking (top line)

Sharpness

Sharpness (normal edge profile or NEP) is quantified by analyzing the profile of the edge itself. The NEP is a measure of width of the transition from the light to dark area. A low NEP indicates a sharper transition from line to background and a correspondingly sharper looking line. A blurry looking, softer-edged line would have a higher NEP value since the transition from line to background would be more gradual.

This attribute is often quantified by measuring rise-time. Rise-time refers to the average number of pixels in the transition from dark to light pixels in a direction orthogonal to the boundary. If an image is blurry, the transition occurs over a large number of pixels. If the image is sharp, the number of pixels in the transition region is minimized.

Negative Line Quality

"Negative lines" (fine white lines contained within solid areas) suffer from the same image quality problems as positive lines. For example, in ink-based systems, wicking, can cause the negative lines to become filled in, while in toner-based systems, toner scatter and overzealous development decrease line detectability and degrade negative line quality.

Detectability can be quantified in several different ways such as by measuring the average line width, the line area, apparent lightness and by determining whether the line has been filled in enough to appear broken.

Tone Reproduction

Tone reproduction measures the actual tonal response of a system. Dot gain characteristics of a given imaging system can have a large impact on the tone reproduction. To quantify tone reproduction, halftones of various area coverages are printed, measured and compared with intended values. The output values are often measured for each primary in a system, sometimes secondary colors, and are commonly repeated for each separate rendering intent. The resulting data sets are often displayed as families of curves (tone reproduction curves) that show the relationships between the intended output and the actual output.

Dimension and Orientation

Image orientation and registration are characterized by measuring the distances between the printed image and the paper boundaries. Skew is the measured angle between the side of the paper and the edge of the printed image. It can be reported either as an angle or as a slope.

Imposition

High quality duplex printing requires control over image imposition (the alignment of an image on one side of the paper with the image on the other side). Measuring imposition can be a composite of registration of each side's image, or it can be accomplished on lighter weight stock by using a transmission measurement to verify alignment. Pre-qualification of a printer's imposition accuracy can best be achieved via a test target rather than a customer original.

Page Size After Cutting

For non-cut sheet presses, dicing processes lend an additional opportunity for quality issues to arise. Misalignment of blades can create non-rectilinear sheets and can degrade output quality. Verifying cut quality can be a simple manual process—an operator can use a guide or a protractor to verify corner squareness. Or it can be more automated and exact—measurement of corner angles can be accomplished using machine vision systems that are designed to analyze image quality, as well as apply dimensional and angular measurements.

Roughness of Cut

Another side effect of the dicing process includes edge roughness of the sheets themselves. This attribute can be quantified in much the same way as printed line edge quality. Edge raggedness can be measured and compared with pre-set tolerances to determine whether blades are adequately sharp and that cuts are of acceptable quality.

Case Studies

Wide format Printing

Analyzing samples on wide format printers can be a challenge.

A recently applied solution consisted of creating an array of 2-dimensional CCD cameras at specific positions along the span of the output. This set-up allows for flexible measurement capabilities while avoiding the hassles of media handling. Dimensional stability can be assessed and tracked via measurement of the distances between various image features. Print fidelity can be assessed by passing specific patterns under the cameras for image capture and analysis. Common attributes are motion quality, jet quality (for inkjet systems), print darkness, aspect ratio, feature alignment and color registration.

An additional benefit of quantitative data is that it can be fed into a database for performance tracking and SPC.

Forms and Label Printing

Form and label printing have specific requirements that make ordinary feature analysis somewhat insufficient in tracking image quality. Testing of optical character recognition and 1-D and 2-D barcode fidelity are all required for many applications. Medical labels, for example, have highly stringent requirements for readability for obvious reasons. Both on-board analysis and off-line analysis are often used to ensure output quality.

Print darkness, consistency, line quality, edge raggedness, and readability of characters and barcodes are several common attributes that are measured, tracked and verified.

Conclusion

Production facilities can benefit by applying quantitative image quality measurements deliberately at various stages in the printing process. Quantitative assessment methods can aid in qualification of materials and output for both proofing and press runs, and characterization of press performance.

Qualification of materials, machines and processes requires well-controlled methods of assessing, tracking, and reporting results. Integrating appropriate equipment and methods into the process can facilitate communication in addition to increasing efficiency by saving both time and materials.

Biography

Mr. Kipman is the founder and president of ImageXpert Inc., an industry leader in automated image quality inspection systems. Prior to founding ImageXpert in 1989, Mr. Kipman worked at Xerox for six years where he developed an optical scanner that was the basis for an automatic reading device for the visually impaired. Mr. Kipman holds a M.S. in mechanical engineering, with a major in electro-optics from the University of Connecticut and a B.S. from the Technion Institute of Technology.