A Portable Image Analysis System for Performing *in situ* Image Quality Measurements

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Abstract

Traditionally, quantitative image quality analytical methods rely on large hardware in fixed installations. There are many situations when portability is required, where these methods need to be easily adapted. Consistency between measurement methods used in the research environment and those performed on-site is often desired. Discrepancies can be avoided through the use of a portable measurement device that has been developed to provide identical measurement methods in the laboratory and in the field. A simple hand-held measurement head including optics and light source is coupled with the power of ImageXpert™ software running on a laptop computer to provide truly portable image quality analysis.

This paper will include a system description including details about the image capture device and image analysis tool. System applicability, capabilities and limitations will be discussed. (Patent is pending.)

Introduction

Imaging and imaging supplies companies have been making the difficult but necessary paradigm shift from relying on subjective image quality assessments to performing truly objective, quantitative image quality analysis. Quantification of image quality has become a critical component in development environments, for use in process control and quality assurance in production environments, and as a tool for competitive benchmarking. With this increase in image quality quantification has come an increased need for robust instrumentation. Traditional image quality measurement systems are comprised of vibration isolation tables, large X-Y translation stages, multiple cameras and sources of illumination, auxiliary instrumentation, document feeders, and system enclosures. Such systems are generally quite large and stationary by design.

There are many situations where evaluation of remotely collected samples is desired. Currently, samples are created and brought to the measurement instrument as physical entities or as electronic image files. Sample transport requires logistical leeway that many operations cannot easily support. Samples can be damaged or lost in transit, and there is a built in time delay between sample collection and data dissemination. Images can be collected and routed electronically but image collection conditions need to be well characterized and well controlled, magnification needs to be known, illumination needs to be standardized and images need to be transmitted to the computer running the analysis. Often, this method can result in a time delay as well since one station is generally used for the analysis of images collected at multiple sites. Ideally, evaluation equipment would exist wherever it is required. However, this is cost and space prohibitive. These conundrums have lead to the development of a truly portable image quality measurement system that provides the analytical power of the larger systems, without being restricted by the same set of constraints.

The Need for a Portable System

The challenges became how to take an existing behemoth image quality system and make it portable, and how to make it of high enough quality, with comparable components and full analytical capabilities. ImageXpress was designed to meet these challenges.

Capabilities

ImageXpress was designed to have the full image quality analysis capabilities of ImageXpert. The software is identical to the larger stand-alone automated ImageXpert system. Measurements can be specified by the system user and saved for future use. Tolerances can be entered if assessment against specification is desired. Customization is simple, however there is an “Operator Mode” that limits access to measurement set-up modules and locations where tolerances are defined.

System Description

ImageXpress is a calibrated, high precision optical measurement system. It provides the full suite of image analysis algorithms familiar from ImageXpert. These algorithms can be used to characterize the quality of media and printed output.

The measurement head assembly (as shown in Figure 1) includes a CCD camera, a set-focal length lens and light source comprised of a series of LEDs arranged at a 45-degree angle to the CCD sensor array. (Patent is pending.)

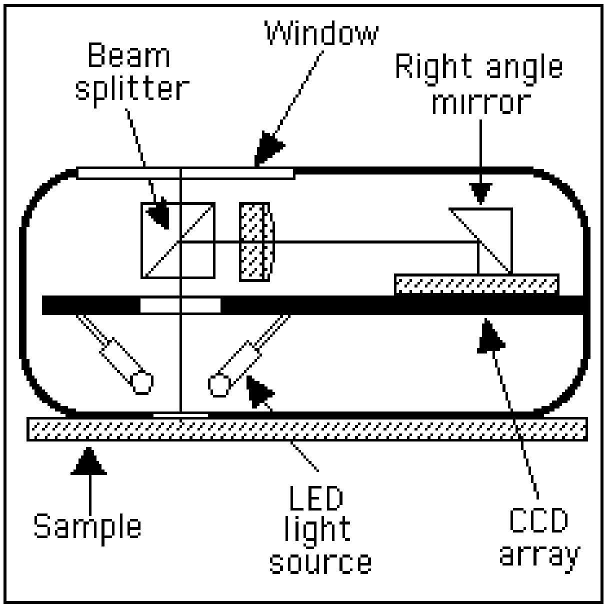

Figure 1: Measurement head assembly schematic

Positioning of the measurement head on the sample is facilitated through a beam splitter and window located in the top of the unit. The operator can see the position of the aperture on the sample.

A portable, flatbed scanner is included for macroscopic image quality analysis and a small light-table is also available for measurements that require transmission capabilities.

Calibration

Camera calibration is critical for repeatable, reliable data. Pixel-based units are translated via the calibration routine into real-world units (English or metric). The ceramic calibration target has high-precision, photolithographically produced features. The ceramic substrate makes the calibration target highly stable over time, and its quality is not degraded by routine cleaning. This is a particular concern for a portable measurement system where target handling and cleaning will occur more often than in stationary systems. The calibration target is accurate to the micron, and is dimensionally precise and accurate to accepted international standards.

Fields of View

For the high magnification measurement head, a field of view spanning 3mm was chosen. This translates into an effective size of approximately 5 microns per pixel. Many printers are now designed to have addressabilities of 1440 dots per inch and higher. The choice of a 5-micron pixel allows three measurement pixels per single dot width rendered at 1440 dpi, which exceeds the Nyquist sampling frequency thereby increasing system robustness. This choice is appropriate for high magnification applications such as dot quality (Figure 2) and line quality (Figure 3) where edge detail and small feature analysis are desired.

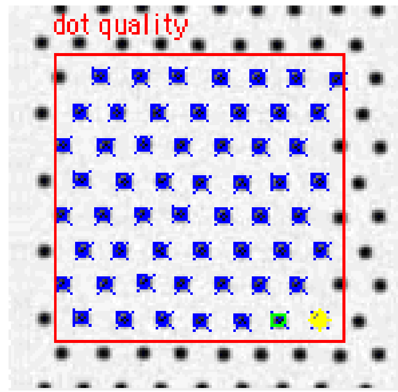

Figure 2: Dot Quality

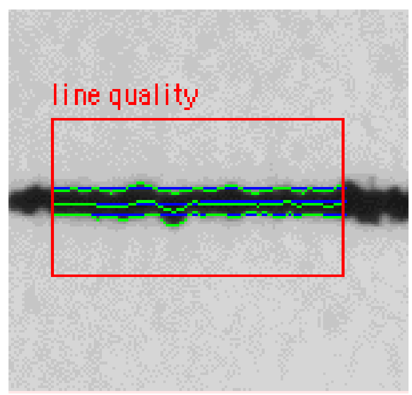

Figure 3: Line Quality

The portable scanner is used for image capture of macroscopic paper and image quality attributes that require a lower spatial sampling rate and a larger field of view such as paper formation, mottle, and banding.

Tradeoffs and limitations

A handheld unit has inherent restrictions on sample volume per unit time. Sample volume is necessarily restricted by the time it takes for manual positioning of both the sample and the measurement head. Manual placement of the high magnification measurement head also impacts test target design. Test target design considerations include larger fields of high magnification features such as lines and dots to enable quick placement of the measurement head over a region of interest. Figure 4 shows a typical test target feature. The 3 mm field of view is shown (to scale but not actual size) as a dotted rectangle superimposed on the image.

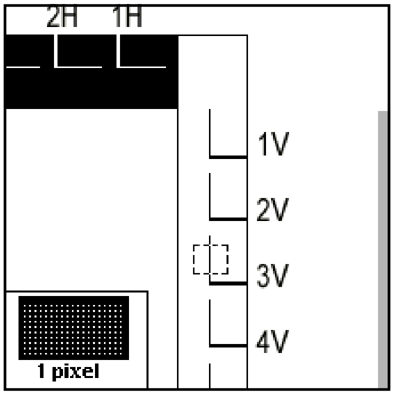

Figure 4: Line array with 3mm FOV rectangle superimposed

Manual measurement head placement can be tedious and difficult with such a small field of view, particularly since test targets are often designed with similar-looking but decidedly different features in close proximity that are not easy to visually differentiate (such as 1-pixel wide lines, 2-pixel wide lines, etc). This can confound the manual measurement head placement process. This test target design approach is standard for machine-vision based automated systems where feature proximity equals efficiency since less time needs to be taken moving a translation stage between measurement positions. However, this test target design approach is far from the most efficient for manual systems.

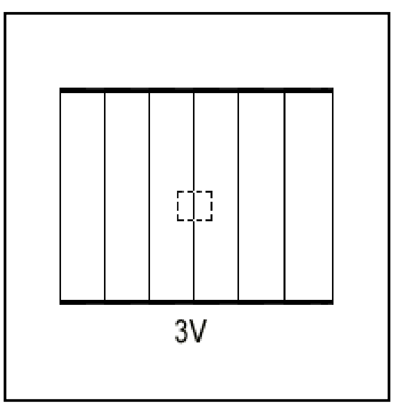

Figure 5: Modified test target with FOV rectangle superimposed

For manual systems, larger fields of identical features increases the efficiency of the human operator in being able to place the measurement head over the feature that is intended. As an example, Figure 5 shows a modified test target with an array of "identical" lines. A dotted rectangle is superimposed on the array to show the 3 mm field of view (to scale but not actual size). A large field of identical features decreases the chance for capturing and measuring the wrong feature. In this design, there are no confounding features in the area. All lines are the same width so the operator has many more degrees of freedom in measurement head placement.

Dynamic Location

Although test target design can make measurement head placement much easier, the feature of interest may not always be centered in the field of view. In order to make measurements of a feature one or more regions of interest (called ROIs) are defined. Processing type, parameters and measurement features area selected for each ROI. If line edge noise is of interest, for example, the ROI would be positioned over the edge, edge processing would be selected, a threshold value might be specified, the orientation and polarity of the edge would be selected as some of the parameters, and then measurement features such as mean deviation of the edge points from the best fit line through them might be selected. If the line moves within the field of view, it might not be detected by the ROI. To account for these variations ImageXpress employs dynamic location.

Dynamic location is a very powerful capability that automatically corrects for image position variations. By locating a fiducial *within the field of view* of the camera, all ROI positions are automatically adjusted to compensate for image position variations. Dynamic location provides adjustments automatically so the measurement head does not need to be manually repositioned to account for small variations in image placement.

The three cases shown in Figures 6a, 6b and 6c prove that as long as the feature remains in the field of view, the software can locate it using dynamic location. This powerful capability of the image analysis system makes precise measurement head placement less critical, which makes the measuring system more robust.

Portable Unit Applications

A portable, image quality measurement tool has a multitude of possible uses.

Paper quality attributes can be characterized in the mill. Raw stock can be characterized using ImageXpress through measurements including dirt count, fiber size and orientation, formation and mottle. The sample can be taken at the mill or production site and analyzed immediately on-location using the same methods as those used in a testing laboratory, providing timely information and feedback on both product and process.

Printability can be quantified in the laboratory. The small footprint of this portable unit is well suited for use in laboratory environments where space is at a premium. The powerful image quality analysis features allow a high level of measurement flexibility and the user interface enables the quick turnaround of results that is so critical in rapid development environments.

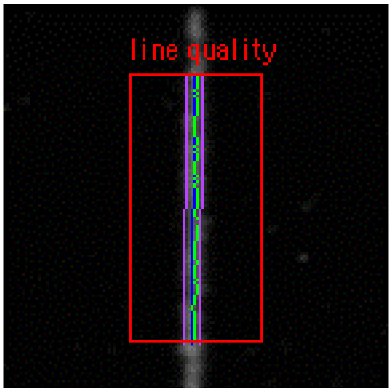

Figure 6a: Sample image centered in field of view and under ROI that is labeled "line quality".

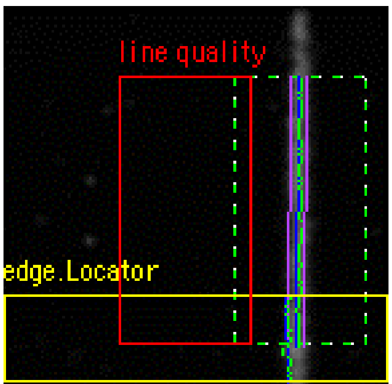

Figure 6b: Sample image with a moderate placement variation. Dotted line shows location of ROI after dynamic location.

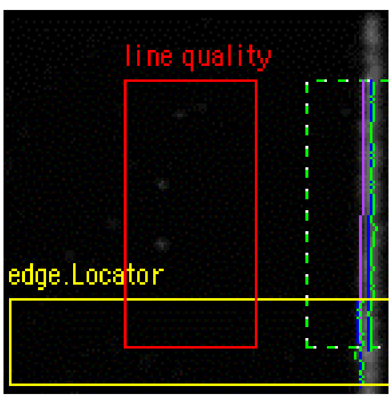

Figure 6c: Sample image with even greater placement variation. Dotted line shows location of ROI after dynamic location.

Image quality can be measured in the field. This portable unit facilitates meaningful on-site print quality analysis. ImageXpress can be used for print performance qualification at new installation sites and allows periodic performance verification at existing locations. Since measurement methods can be identical to those used on the production line, actual performance can be evaluated against design specifications. ImageXpress also enables on-site trouble shooting and process optimization with immediate feedback regarding system performance.

Vendor performance can be pre-qualified and verified. ImageXpress enhances the ability of customers to pre-quality vendors during the selection process and confirm compliance of established suppliers. Conversely, it also allows vendors to demonstrate that their product meets specified customer requirements.

Benchmarking can be performed in any venue. ImageXpress offers the flexibility to perform competitive benchmarking in a variety of situations both in-house and in the field.

Conclusion

ImageXpress is a very robust and capable tool for performing *in situ* image quality measurements. The full suite of image analysis capabilities familiar from ImageXpert provides flexible and customizable measurement algorithms via an easy to use menu driven user interface. Measurement methods employed in the lab can now be taken into the field, increasing consistency and facilitating communication between sites.

Biography

Dave Wolin received his Bachelor's degree in Physics from Cornell University, and has spent the last twenty years working in the field of imaging. He has been involved in the development and production of imaging sensors and systems for a variety of applications. Since joining KDY Inc. as Technical Marketing Manager, he has been working on metrics for image quality analysis of printers and media.