

Automating Image Quality Analysis

Dave Wolin, Kate Johnson, and Yair Kipman
KDY Inc.

Nashua, New Hampshire
www.imagexpert.com

Abstract

Print quality assessment has traditionally relied on the subjective judgment of human observers. As printing technology has evolved and prices have plummeted, image quality has become an increasingly vital differentiator between competing products. Consequently, there is an expanding need for repeatable, reliable, and objective image quality assessment tools. An automated image quality measurement system would provide the ability to measure a large volume of prints as well as the objectivity and repeatability required for quality control and failure analysis.

A measurement instrument comprised of a computerized image capture system, high quality, high resolution imaging equipment, powerful image analysis software and integrated motion control would provide a flexible solution to the user who desires automated analysis of multiple image attributes. Automated image quality measurement equipment would be useful in research and development environments by providing timely performance feedback during product development, as well as objective benchmarking and competitive analysis. In production environments, an automated system could be integrated into the manufacturing process to be used for statistical process control and failure analysis.

Results from an automated image quality measurement system should be validated through calibration and verification procedures and tools. These processes should include the use of calibration targets with features that are traceable to standards institutes.

In this paper, we will be discussing the increasing need for automated image quality measurement systems and the benefits that such systems provide. We will show how automation can be used to augment traditional print evaluation techniques. We will also be discussing in detail a system that has been successfully integrated into both research and production environments.

Quantitative Analysis

Historically, image quality assessment has been largely subjective although often augmented with the addition of a few specialized pieces of equipment (such as glossmeters, spectrophotometers, and microscopes). Obviously this approach does not support high volume testing nor does it result in the objective, repeatable data required for statistical process control and other forms of performance tracking. However, quantitative results are meaningless unless they

are presented and interpreted in the context of the specific application that is being analyzed. For example, suppose some line quality measurement results in a value of 0.2 mm. The number itself does not indicate anything about its acceptability to the final observer. If the design engineers know that they need a certain line quality measurement to be under 0.1 mm in order for the line to be of acceptable quality to their final human observer, or if they know the acceptable value is at most 0.5 mm for their machine vision system, then they are able to interpret the results in some meaningful way. Obviously, the interpretation is completely dependent on the context.

The correlation of quantitative measurements and subjective judgments for the specific application and its intended audience is a critical step in any objective measurement system.

Automation

Automation has long been an integrated process in production environments. Increased throughput, decreased error due to operator intervention and the output of reliable quantitative data are some of the benefits of automated image quality measurement systems.

The use of automation in research environments is not as familiar. However, automation provides the repeatability and reliability necessary to determine how system changes are affecting image quality without having to spend an inordinate amount of time trying to repeatably position samples under a microscope and without having to filter out the inherent variations in judgments made by human observers.

Meeting the Needs of the Customer

One of the most important considerations when choosing an automated image quality measurement system is whether it will truly meet the immediate and long term needs of the user. Important questions include: Is the system calibrated? Is the system easy to use? Is it flexible? Does it support multiple or custom test targets? How about multiple cameras? Can peripheral instrumentation be easily integrated into the system? Does the system allow for on-the-fly changes without having to contact the vendor? How easy is it to develop, modify, and add new metrics? Can it automatically compensate for changes in target placement? Is there a feature that enables automatic comparison of measurement results against tolerances? Is there an operator

mode that protects measurements and tolerances against inadvertent modifications?

Calibration

System calibration is the most basic and the most important requirement in any image quality measurement system. It is critical to calibrate the camera(s) and to verify focus, magnification, and illumination. Many image quality measurements require resolution of a few microns per pixel. As a result, the calibration and verification routines require the use of a stable, high precision calibration target.

The importance of system calibration and verification cannot be overstated. Data collected from an uncalibrated instrument will be of little or no value.

The following figure shows one example of a multi-purpose calibration target currently being used by ImageXpert™, an automated image quality measurement system from KDY Inc. This target is designed to provide precision features and fabricated using processes that guarantee that they are accurate to the micron level. The materials used in producing this target make it very physically stable and durable.

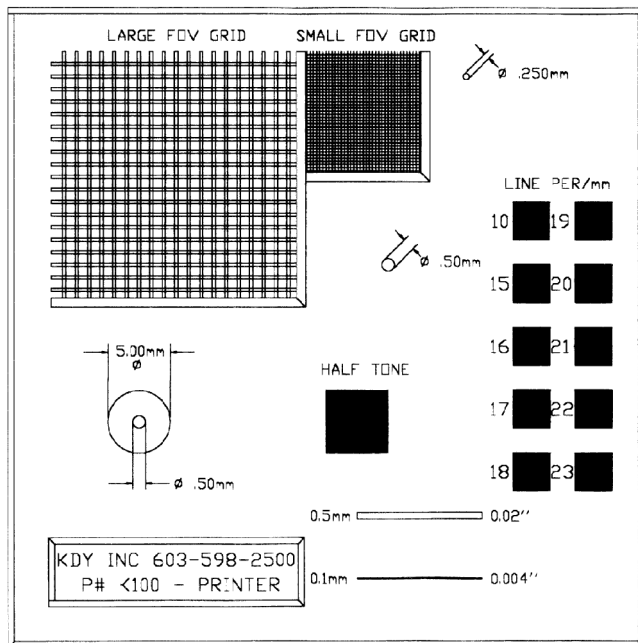


Figure 1: Calibration Target

Flexibility and Ease of Use

ImageXpert is a highly flexible system. It does not require the use of a specific test target. It can measure any number of image quality features at any number of locations on any number of test targets. The ImageXpert system does not require any programming for custom metric development or modification, sequence building, motion control or automation. Code writing is not necessary because it has been replaced by pull-down menus and GUI's that allow users to customize the system to fit their specific needs

simply by pointing and clicking. Since there is no need for specialized programming, customization can be made on-the-fly by the system users without any intervention by KDY. This flexibility allows the user to be in complete control of the system.

Image Acquisition Hardware

ImageXpert has a flexible image acquisition system which can be configured to include one or more cameras depending on the specific needs of the user. The ability to support multiple cameras simultaneously provides users with extensive measurement capabilities. Large field of view (FOV) cameras are desirable for large area analysis such as image offset and OCR, while small FOV cameras are required for high magnification image measurements such as line quality, dot quality, or resolution. In addition, cameras are available with variable integration time to compensate for low light levels.

In order to ensure uniform illumination, every camera included in the system has its own individual source of illumination: a high-frequency fluorescent ring light.

Peripheral Image Quality Measurement Instrumentation

In many cases, additional instrumentation is desired for more specialized measurements of image attributes such as gloss, color, and density. ImageXpert has an integrated spectrophotometer for color measurement, a spectrodensitometer for density measurement, and a glossmeter to perform these types of specialized tasks. These instruments are integrated into the system and can be controlled directly through the ImageXpert software. Measurement automation can be enabled by teaching the system specific measurement locations and then simply indicating the type of measurement to be performed. This type of measurement set-up is done through the same user-friendly GUI and menu structure as the camera-based operations.

Sequences, Dynamic Location, and Dynamic Threshold Finding

The success of an automated system relies on its ability to run series of multiple measurements without operator intervention. This requires the development of measurement sequences that specify which regions to measure and which measurements to apply to those regions. These sequences can be built very quickly on ImageXpert by using simple point-and-click operations. Sequences can be saved for later use, and modifications can be made at any time.

Regions of interest (ROI's) are delineated graphically using both rectilinear and free-form shapes depending on the needs of the user. Each of these regions can include multiple measurements. ROI's can also be superimposed if measurements requiring very different processing types are desired for features contained within the same area.

Since there are often variations in image placement on a page as well as in sample placement under the camera, ImageXpert can be enabled to perform dynamic location.

Dynamic location readjusts measurement positions relative to some user-defined fixed point or fiducial. A set of horizontal and vertical edges can be used (as could any number of other features) to train the system on the desired locations of the measurement regions. Once the sequence is run, this feature compensates for small changes in image placement based on the relative positions of the fiducials to their ideal locations.

Many of ImageXpert's image quality metrics are threshold dependent. During sequence set-up, thresholds are specified for each measurement. Threshold values can be chosen directly or they can be determined by any mathematical relationship between the foreground and the background intensity in the field of view. What happens if there is a change in the illumination level or in the gray value of the substrate? ImageXpert allows the user to enable dynamic threshold finding that automatically compensates for changes in lightness by shifting the threshold values accordingly.

Integrated Motion Control

Another desirable feature in automated image quality measurement systems for hardcopy output is motion control. A high precision X-Y translation table can enable repeatable positioning of test targets under the camera being used for image capture. ImageXpert has fully integrated motion (including a vacuum chuck to ensure sample flatness, and a vibration isolation table to guarantee stability during image capture). Users can easily train the system to go to specific points on any test target. In a macro building shell (also programmed solely by point-and-click rather than code writing) users can take advantage of this positioning by specifying which measurements are to be taken at each location in whatever order the user wants. System users can build multiple "tasks" that correspond to different test targets or different types of testing. These positions and tasks can be saved for future use and modification.

Dynamic Image Offset

In addition to the small image placement changes that can be compensated for by using dynamic location, larger image position variations can also occur. ImageXpert allows the user to train the system to look for a fiducial and shift all positions according to whatever offset is found between the ideal fiducial placement and the actual location. This is done using a wide field of view camera. Once this has been accomplished, dynamic location is used to compensate for any residual position errors.

Dynamic image offset can be used in conjunction with the tasks that specify which positions to go to and which measurement sequences to apply at each location. As dynamic offset compensates for image placement variations by shifting all positions relative to the offset that is detected, the user has an option to use vision guided motion (VGM) to adjust all positions requested in a task relative to an offset that is measured at the beginning of the task.

Dynamic offset is a very powerful feature that allows a higher level of system automation than systems without

this capability since no operator intervention is required for tedious manual target repositioning. Large numbers of prints or media samples can be measured consecutively.

Data Flow

In order to have maximum flexibility, the system should provide data in a format that is easily incorporated into whatever analysis program the user chooses. Constraining the data format to a program chosen by the vendor assumes that users will be able to adapt their processes to accommodate the software. Ideally, users can simply import the data into whatever program they are currently using.

ImageXpert also enables network capabilities. Image capture, image analysis, and analysis reporting can all take place on different computers. Some users of the system find that images are collected at multiple sites and then the image analysis software goes to those sites to retrieve images, processing takes place automatically based on image names, and then data reports are sent to another location for interpretation. Being able to choose between multiple configurations enables users to adapt the system to their processes rather than adapt their processes to the system.

The Role of Tolerances

In order for an automated system to really enable maximum production throughput, there must be some way to test the measurement results to user-defined tolerances. ImageXpert provides the user with this ability within the context of each measurement. In addition, the user is able to choose which measurements should be evaluated for pass/fail, which should just report results without causing a pass/fail and which measurements should not show up on a report at all (such as two measurements that are subtracted where the difference is the figure of merit rather than the individual values). Once tolerances are entered, the software indicates a status of pass or fail. Tolerances are as easily changed as the measurements themselves.

Operator Mode

Once measurement sequences are created, tolerances chosen and points trained, it is good to have some way of maintaining the integrity of the set up. ImageXpert has an operator mode which provides access to the underlying sequences to anyone who knows the password (determined by the user) but blocks entrance for everyone else. In this way, tolerances can not be changed at whim nor can measurements be modified. This is always important but it is particularly important when there are multiple stations running the same tests.

Conclusion

Automating image quality analysis enables increased throughput, and repeatable reliable data in both R&D and production environments. When choosing an automated system, users should make sure that the system suits both

their immediate and long term needs. Most importantly, the system should be calibrated. It should also be easy to use and flexible enough to handle any test target that the user wants. It should not restrict the user to a specific test target. On-the-fly changes should be easy to make without having any vendor intervention. To maximize automation, make sure it can automatically compensate for changes in illumination level and target placement and that it can automatically compare measurement results against tolerances. An operator mode that protects measurements and tolerances against inadvertent modifications is also important if the system is going to be used in production environments.

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 image quality metrics for print and media analysis.