PIAS-II™ – A High-Performance Portable Tool for Print Quality Analysis Anytime, Anywhere

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Achieving optimal print quality is critical to the digital printing enterprise. The PIAS (Personal Image Analysis System) was introduced by QEA in 2001 to enable quick, quantitative print quality evaluation. Since then the PIAS, an innovative handheld device, has been widely adopted for R&D, production QC and a host of problem-solving applications. The new PIAS-II, introduced in 2006, builds on the strengths and the success of its predecessor. Portable, low-cost and user-friendly, the PIAS-II makes objective print quality analysis possible for every imaging professional. The ability to visualize, quantify and communicate print quality precisely, reliably and whenever needed is essential if the digital printing industry is to continue its long history of advancement. In this paper, the PIAS-II architecture and software tools are described. PIAS-II capabilities and potential are discussed, using application examples from a case study.

1. Introduction

In the digital printing enterprise, print quality is a critical decision factor for applications from business communications to digital photography and beyond. Despite its importance, print quality (PQ) remains somewhat elusive. The concept of print quality can seem vague; methods of evaluating PQ are historically subjective and lacking in precision; universal agreement on print quality standards, particularly international standards[1], has not been achieved; and quantitative measurement tools have generally been available only to a handful of experts.

A leading supplier of instrumentation to the imaging industry for two decades, QEA has heard the call for more widely-available measurement tools. Imaging professionals need tools to help improve performance in the essential imaging tasks, tools that deliver fast, objective feedback on the quality of the professionals' own work, whether in the laboratory, on the shop floor or in the field.

The PIAS[2] went a long way toward meeting this demand, and its introduction marked the first stages of a revolution to democratize the esoteric realm of print quality analysis. But there were many more professionals out there who needed the analytical power, speed and portability of a PIAS, for whom price remained a stumbling-block. Introduction of the PIAS-II makes an enhanced PIAS analysis toolkit available to those professionals, and at a price that is making quantitative PQ analysis the norm and no longer the exception.

Technically, the PIAS-II is not a single tool but a family of tools. It is designed to satisfy today's needs for objectivity and efficiency in print quality analysis. At the same time, it is positioned to meet tomorrow's challenges as digital printing continues to grow in new and diverse directions.

2. Objective Print Quality Analysis and PQ Tools

Whatever the application—product planning, engineering, manufacturing, marketing, competitive benchmarking, and many others—quantitative print quality analysis is essential for objective decision-making and effective communication. While unanimity on PQ evaluation methods and standards remains elusive, it doesn't need to be: we do have the data and the tools for making PQ analysis consistent within companies and across the industry. Essentially, four categories of PQ attributes constitute a basic checklist for most imaging applications:

1) Tone and color reproduction
2) Resolution (sharpness and detail)
3) Image artifacts (print defects)
4) Gloss and distinctness of image (DOI)

These attributes also provide a framework for developers of instrumentation like QEA for planning relevant products and designing appropriate hardware and software functionality.

2-1. Tone and Color Reproduction

Tone and color are among the most telling PQ attributes. In typical practice, they are measured using a

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densitometer or spectrophotometer—important tools used by the imaging industry for decades. The PIAS-II does not replace these tools, but complements them with equally important new capabilities.

Typically, densitometers and spectrophotometers are "large" aperture devices (usually > 4mm in diameter). As such, they are used for measuring the average reflectance, density or color of a region of interest, but not its non-uniformity within the aperture. The PIAS-II, in contrast, is designed to analyze image structures and is therefore well suited for non-uniformity and image noise measurements and the quantification of tone and color reproduction.

Although an image analysis system like the PIAS-II is not built specifically for density and color measurements, the PIAS-II is capable of providing density and color readings in addition to spatial measurements. The system is factory-calibrated in both reflectance and spatial dimensions to ensure meaningful, accurate and consistent measurements.

2.2. Sharpness, Detail and Image Defects

The ability of a printing system to produce (or reproduce) a sharp image with distinct detail is fundamental to high-quality output. Being able to measure image structure attributes such as sharpness and detail is what differentiates an image analysis system and distinguishes it from a conventional densitometer or spectrophotometer.

A typical image analysis system consists of a digital camera (or scanner) that captures a region of interest and analyzes the PQ attributes of the digitized image. Since human perception of PQ depends on the "scale" of the image structure, it is important for an image analysis system to be able to vary the scale of the analysis in both resolution and aperture size. The PIAS-II meets this requirement with its interchangeable optical modules.

Equipped with both high- and low-resolution optical modules, the PIAS-II comes ready to tackle the long list of PQ attributes of practical interest. The most important of these attributes are:

1) Line and edge quality (line width, blurriness, raggedness, contrast, fill, and darkness)
2) Text quality (stroke quality, fidelity, uniformity)
3) Dot quality (dot gain, dot shape, and placement)
4) Adjacency and inter-color bleed
5) Graininess, mottle and image noise
6) Banding, streaking
7) Inkjet satellites and toner background
8) Ghosting
9) Color registration error
10) Resolution and Modulation Transfer Function

2.3. Gloss and Distinctness of Image

In business communications (marketing literature, for example), gloss is an especially important print quality attribute. In digital photography, DOI (distinctness of Image)[3] is of equal importance. Gloss and DOI measurements usually require dedicated instruments. However, with its interchangeable optics design, the PIAS-II is open to future expansions to include gloss, DOI, and other applications that may require special optics and illumination geometries..

3. The PIAS-II Design

The PIAS-II is compact and light-weight (~12oz / 350g). Originally designed for PC, it works equally well with Intel-based Mac computers from Apple. Fig. 1 shows the basic PIAS-II unit (the measurement head/camera module with one of its optical modules installed) and a second optical module. The modular optics design greatly expands the user's ability to analyze PQ at different scales using different resolutions and apertures. Currently, two optical modules (with resolutions of ~5μm and 37μm per pixel) and several types of illuminations (visible, UV and IR) are available. The standard optical arrangement is 45/0 geometry, typical for reflective, densitometric measurements. Other specialized optical arrangements are also being made available.

Fig. 1 The PIAS-II with an optional optical head in the foreground. Dimensions of the main unit are approx. 100mm (H) x 80mm (D) x 60mm (W).

PIAS-II software is designed for easy expansion as improvements and new tools become available, whether from QEA or the user. The PIAS-II exemplifies a design philosophy that uses international and industry standards for the highest data compatibility among users. In keeping with this philosophy, the PIAS-II technology

incorporates ISO-13660[4] measurement algorithms. The success we have experienced with this approach is testimony to the importance of print quality standards, and especially international standards, in the global world of imaging.

4. Using the PIAS-II

To run a test, the user attaches one of the system's optical modules to the measurement head/camera module, connects the unit to the computer with a USB 2.0 interface, and launches the software. The system is now ready to perform a myriad of built-in PQ analyses. Typically, in live preview mode the user locates an image feature to be analyzed, defines a region of interest (ROI) and from the toolbox on the screen selects the analysis to be performed. Results appear almost instantaneously. The sophistication of the PIAS-II is such that while the full range of measurement parameters are under user control, default parameters can often be used instead, so that most analyses are executed by a single click of the mouse, or a push of a button.

PIAS-II analysis results are displayed in both numerical and graphical form. The user can display contours, bounding boxes, center marks, and ROIs for the image features analyzed. A key strength of the PIAS-II is the ease of generating test reports. Results (both graphical and numerical) can be saved or exported in real time to other applications such as Microsoft Excel®. A Data Logging function is designed to enhance productivity: as the user makes measurements, results can automatically be logged to a text file for further analysis or reporting.

5. Application Examples – A Case Study

Results from a benchmarking study of two high-speed electrophotographic color printers illustrate the capabilities of the PIAS-II. The study used test targets designed to analyze photographic images and business graphics, as shown in Fig. 2. The study measured a full spectrum of PQ attributes; due to length constraints here, however, only selected results will be highlighted.

Fig. 2 Test Targets in the Benchmarking Study

5.1 Tone, Graininess, Noise and Banding

As noted, tone reproduction is fundamental to print quality. Fig. 3 compares the lightness (L*) measured by the PIAS-II in Printers A and B. The tone curves of the two printers are quite comparable. Photographic images from the two printers examined visually also appeared very similar in tonal quality. Tone, density and color measurements are easily performed with the PIAS-II Area tool. Such measurements, as we have seen, can also be performed with a densitometer or spectrophotometer. But what is significant here is that the PIAS-II not only performs tone reproduction measurements; it also measures non-uniformities in tone, i.e., graininess and mottle, as illustrated in Fig. 4. (PIAS-II graininess and mottle measurements are computed based on ISO-13660 methodology.) Case study results show that while tone reproduction characteristics of the two printers are similar, the graininess of photographic images is clearly different. Visual inspection supported the quantitative results.

PIAS-II users can choose different optical resolutions and apertures. For graininess, mottle and tone measurements, the low resolution optical module (~37µm/pixel or 686ppi) provides the best correlation with visual inspection results.

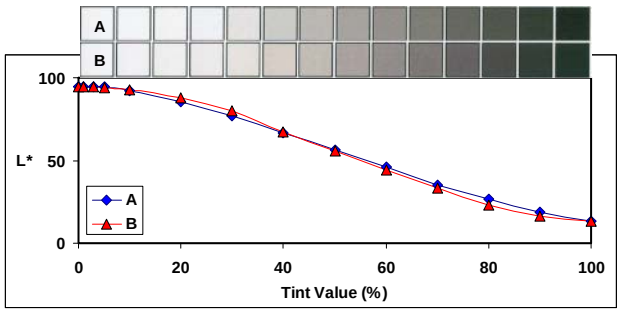

Fig. 3 Tone reproduction measurements

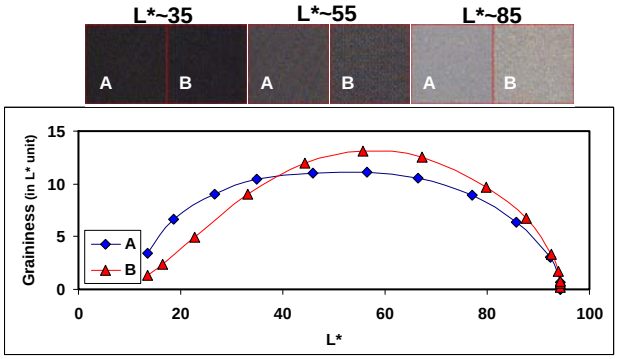

Fig. 4 Graininess measurements

Another powerful PIAS-II feature for image noise measurement is the Noise Power Spectrum (NPS) tool. The NPS tool performs a 1D Fourier Transform on the reflectance profile to obtain the Weiner spectrum, which measures the noise variance at each spatial frequency,

providing a detailed analysis of image noise. Fig. 5 compares the noise power spectra of Printers A and B for a midtone patch simulating a skin tone. The results of this analysis are consistent with those obtained in the graininess measurements shown in Fig. 4.

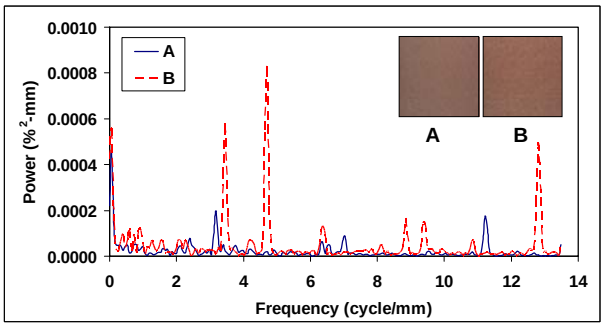

Fig. 5 Noise Power Spectrum

An extension of the NPS tool is the Banding tool, which builds on the NPS tool by adding a digital filter to the NPS output. The filter is a so-called "Visual Transfer Function (VTF)" that simulates the spatial sensitivity of the human eye. This tool is useful for correlating quantitative banding analyses with visual inspection results. The output of a banding analysis is very similar to the NPS results, with the high- and low-frequency response attenuated as defined by the VTF.

5.2 Sharpness and Detail: Line, Text and MTF

Line and text quality are typically analyzed with the high-resolution optical module (~5μm per pixel or 5080ppi) installed and the Line Tool activated. ISO-13660 provides the algorithms underpinning the line property computations. Fig. 6 compares line widths measured for Printers A and B. We can see that Printer B produces lines in conformity with target line widths, while Printer A's line reproduction shows marked inconsistencies.

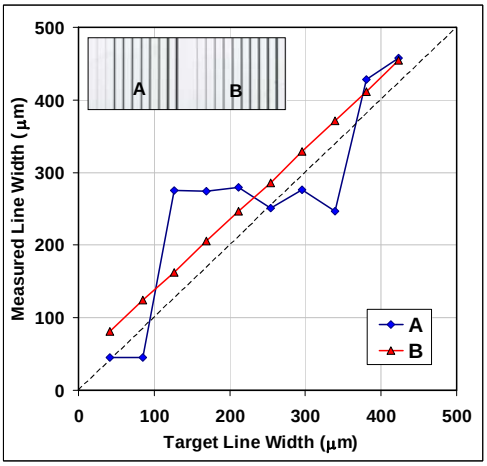

Fig. 6. Line Width Measurement

For analyzing resolution (the ability of a printing system to reproduce detail), the PIAS-II incorporates the SFR (Spatial Frequency Response) tool. This tool is based on the ISO-12233[5] method of measuring the spatial frequency response to a slanted edge. Interpretation of an SFR curve is the same as MTF (Modulation Transfer Function). The advantage of the SFR tool is its simplicity and efficiency in getting the MTF of a printing system.

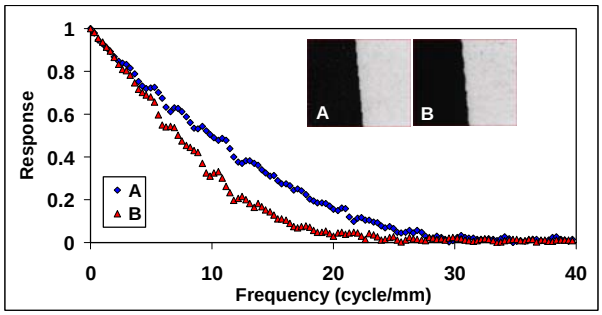

Fig. 7 Spatial Frequency Response for MTF

As shown in Fig. 7, Printer A has a better spatial frequency response, and hence higher resolution and a better MTF, than Printer B.

5.3 Toner Background

Toner background is a serious PQ problem in EP printing. The PIAS-II Background tool makes background analysis quick and reliable. Details will be reported elsewhere due to space limitations.

6. Summary

The PIAS-II, a new portable, low-cost, easy-to-use image analysis system, is now available. The PIAS-II places a powerful set of analytical tools within reach of any imaging professional who needs fast, objective means of evaluating print quality. The PIAS-II can be used with any printing technology and can quantify image quality on any medium. As digital printing applications evolve, the flexible PIAS-II architecture is designed to grow with them.

References

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5) ISO12233:2000 Photography-Electronic still-picture cameras-resolution measurements