Applications of ISO-13660, A New International Standard for Objective Print Quality Evaluation

John C. Briggs, Alice H. Klein, and Ming-Kai Tse
QEA, Inc.
755 Middlesex Turnpike, Unit 3, Billerica MA 01821 USA
Tel: (978) 528-2034 · Fax: (978) 528-2033
e-mail: info@qea.com
URL: www.qea.com

Paper presented at Japan Hardcopy '99
Imaging Society of Japan
July 21-23, 1999, Tokyo, Japan

Applications of ISO-13660, A New International Standard for Objective Print Quality Evaluation

John C. Briggs, Alice H. Klein and Ming-Kai Tse

QEA, Inc., Burlington, Massachusetts, USA

ABSTRACT: ISO-13660, a first-of-its-kind print quality standard, is about to be issued. ISO-13660 is intended as a practical, objective means of communication about basic image quality parameters and provides measurement methods that lend themselves to automation. Though much work remains to be done before it can be considered definitive, ISO-13660 represents a tremendous advance, laying out the first world-wide industry standard for digital print quality. QEA is an early adopter of the standard in its commercially-available automated image quality analysis system. At QEA, intensive day-to-day use of ISO-13660 for more than a year has shown both its considerable strengths and some of its limitations, pointing the way to some significant enhancements. In this paper, we will share our experience in the use of ISO-13660 to measure print quality in real-world applications, from print engine development to media benchmarking. The print quality metrics and measurement protocols defined in the standard are reviewed. The strengths of the standard, such as its dynamic threshold-setting technique, are demonstrated. Some of the limitations of the standard will also be discussed, for example, difficulty in finding the 10% and 90% thresholds reliably, and weaknesses in the definitions of raggedness, graininess and mottle. Suggested changes to the measurement protocols are proposed for overcoming such limitations.

Introduction

How we perceive the quality of a printed page depends on the total impact of the many attributes[*] of the printed image. These attributes can include text darkness, line raggedness and a host of other effects resulting from the quality of the basic image elements, such as lines and solid areas, on the page.

While the attributes of a print are critical to our perception of print quality (PQ), defining them is no simple task. Something as simple as quantifying the width of a printed line can be approached in many different ways and raises many important questions. What threshold indicates the edge of the line versus the beginning of the field? Should line width be measured at the widest point, the narrowest point, or averaged? How should the measurement instrument be calibrated? Without appropriate answers, differing assumptions and methods of analysis produce inconsistent results. The confusion becomes even more serious if the attribute to be quantified is ill-defined, such as uniformity of fill (mottle). Until now, an accepted mechanism for resolving these uncertainties has not existed.

[*] What are termed print quality attributes in this paper are sometimes known as PQ *metrics*[1] *or physical image parameters* (PIP's)[2]

In the absence of a widely-accepted PQ standard, some companies have developed their own. Many large imaging companies, e.g. Xerox and Kodak, have developed proprietary standards and in some cases their own measurement equipment. Such steps may help make internal discussions of PQ more consistent, but without a PQ standard and the commercial availability of standards-based instruments, communication between organizations, internal or external, remains a problem.

Accepted definitions of PQ attributes and measurement techniques are needed to facilitate communications among all concerned, including R&D, quality control, marketing and purchasing. Indeed, some basic PQ attributes, such as density, gloss,[3] color measurement,[4] and others, have been defined in international standards for many years. But others are much more recent, are only now under discussion, or have yet to be undertaken. ISO-13660[5] is intended to provide the printing industry with a unified and evolving standard for communicating print quality.

ISO-13660

Developed over the last few years and due to be issued soon,[6,7] ISO-13660 is the first international standard to incorporate a wide range of print quality attributes. The purpose of the standard is to define procedures and algorithms for quantifying basic print quality attributes, as shown in Table 1. Character and line attributes defined include blurriness, raggedness, line width, character darkness, contrast, fill, and extraneous marks and background haze in the character field. Large area attributes defined include large area darkness and background haze, graininess and mottle, extraneous background marks, and voids. Together, the fourteen attributes defined in ISO-13660 provide the tools for solving many PQ problems. The measurement procedures used are intended to be simple and unambiguous and to lend themselves to automation. The standard is intended for black and white prints on hardcopy, though it is clearly extensible to color. Detailed descriptions of the PQ attributes and measurement methods are available in the standard[5] and in other literature.[6,7]

Table 1: ISO PQ Attributes

Character and Line	Large Area
1. Blurriness	1. Darkness, large area
2. Raggedness	2. Background Haze
3. Line width	3. Graininess
4. Darkness, character	4. Mottle
5. Contrast	5. Extraneous marks, background
6. Fill	6. Voids
7. Extraneous marks, character field	
8. Background haze, character field	

The standard is device independent – the image measured can be a laser print, an inkjet print, a pencil drawing, etc. Intended for text and graphics, the measurements specified can be made on any character (text), line, or large area. Thus, no specific test images are required. The standard does not require a specific measurement device, but sets forth compliance requirements for the device.

The standard leaves setting acceptance criteria to the user. Once PQ measurements have been made, it is up to those involved to determine if the print quality is acceptable.

Implementation of ISO-13660

ISO-13660 assumes that the image to be analyzed will be acquired digitally. This can be done with a flatbed scanner, a microdensitometer, or a CCD camera with a digitizer. Any device may be used as long as it is capable of digitizing the image at a minimum of 600 dpi (dots per inch).

The choice of image acquisition device is controlled by a number of trade-offs. Scanners of the flatbed 600 dpi variety offer the advantage of low cost and can easily acquire the entire page area. However, these scanners tends to lack the resolution needed for accurately measuring certain line attributes such as raggedness. Microdensitometers are very accurate high resolution devices but tend to be expensive and slow. A CCD camera-based system has a combination of features especially well suited to PQ analysis. The resolution can be very high, 300,000 to 2,000,000 pixels can be acquired in a single frame, and the cost is reasonably low. Since a CCD camera-based system typically captures only a small section of the printed page at a time, coupling the camera to an automated motion stage is generally necessary.

The first commercially available PQ analysis system to incorporate the ISO-13660 standard was developed by QEA, Inc.[8] The system, typically configured with a CCD camera, is illustrated in Fig. 1. It includes a vacuum-equipped X-Y motion stage for positioning and holding samples.

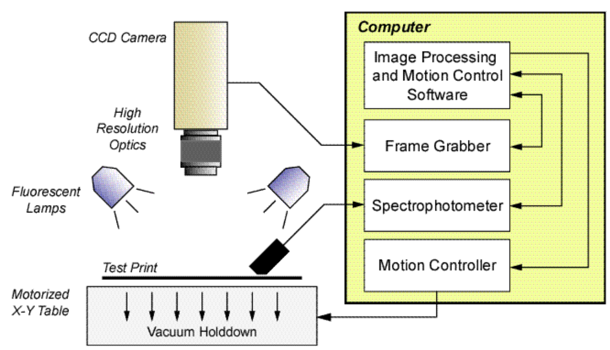

Figure 1 : Schematic representation of QEA's IAS-1000 Automated Image Analysis System

Strengths of ISO-13660

It is notoriously difficult to get a group of people from different organizations to agree on PQ analysis methods. For this reason, the ISO-13660 standards committee sought consensus on those PQ attributes that could most easily be agreed upon. They wanted to establish a starting point from which a more comprehensive standard could be developed, intending that PQ attributes would be added later as methods could be agreed upon. This has proved to be a fruitful approach.

Several aspects of the standard are noteworthy, but two in particular could substantially change the world of print quality measurement.

The first of these is the standardization of PQ measurement methods. Over the years, since standardized methods have been unavailable, researchers have developed many disparate methods for measuring PQ attributes. Inevitably, this has meant that much discussion has focused on defining attributes and defending measurement techniques rather than on solving product performance problems. With widespread adoption, ISO-13660 will give the printing industry a shared terminology and methodology, and shift the focus to more productive issues.

The second key aspect of ISO-13660 is the requirement that a PQ evaluation system use calibrated spatial and density units, e.g. length and distance in µm and density in percent reflectance. Today, some scanner- and camera-based systems output data in uncalibrated units such as pixels and GSV (gray scale value, e.g., 0 to 255) units. But using uncalibrated units means that data from one system cannot be compared with data from another, and repeatability is often poor. Using calibrated units is fundamental to print quality analysis: data from different systems can be compared and repeatability is greatly improved.

Some of the ISO-13660 methodologies are especially noteworthy. The technique for measuring line width is a good illustration. The standard defines the reflectance of the substrate (white) and the colorant (black) to be R_{max} and R_{min}, respectively. The edge contours of the line are defined as the point of 60% transition between R_{max} and R_{min}, as given in this equation:

$$R_{60} = R_{max} - 60\% \, (R_{max} - R_{min})$$

Similarly, edge sharpness is based on the 90% and 10% inner and outer boundary edges. R_{90} and R_{10} are derived by the method shown above. This approach is effectively an adaptive edge thresholding technique and is very robust to variations in the paper brightness or ink darkness.

ISO-13660 offers other advantages. Its measurement procedures are simple, generally well defined, and easily understood. Our intensive use of the draft standard during the last year and a half has shown that the fourteen PQ attributes already defined are applicable to solving a wide range of print quality problems.

Limitations of ISO-13660

Clearly, ISO-13660 already embodies many well worked out techniques. However, it is through widespread use that the standard will be refined and enhanced over time, and with this in mind a few limitations should be pointed out.

The definition of raggedness appears to be incomplete in two respects: neither limits on the fineness of the sampling nor the maximum length of the line segment sampled is specified.

The standard stipulates sampling of at least 23.6 dots per mm (600 dpi) or one sample every 42.3 µm, but imposes no limit on how finely the edge can be sampled. This presents a problem, because finer sampling can result in higher raggedness values, even though raggedness at these wavelengths has low perceptability.[9] The standard should require that the data be filtered to closely approximate a 600 dpi edge sampling.

The standard calls for the lines sampled to be at least 1.25 mm long but gives no upper limit. This too can pose a problem since longer lines, e.g. 10 mm, generally have some curvature that tends to dominate the raggedness value. Two sets of results, one derived from a 1.25 mm sample and the other from a 10 mm sample may be quite different even if the raggedness is discernibly the same. The standard should require either a fixed measurement length, or it should specify a high pass filter to be applied to the tangential edge profile. For now, users should report the measurement length along with the raggedness values.

Line edge blurriness measurement is another area needing refinement. Blurriness is defined in the standard as the distance between the R_{10} and R_{90} thresholds. Our experience has been that because the R_{10} threshold is typically in a region of low slope in the reflectance profile it tends to have poor repeatability. In contrast, the R_{20} threshold generally occurs in a region of sharper transition in the profile and appears to give more reliable results.

There is also room for improvement in ISO-13660's graininess and mottle methods. The standard defines graininess as non-uniformity occurring on a scale less than 1.27 mm but greater than 42.3 µm and mottle as occurring on a scale greater than 1.27 mm. This fixed size cutoff between graininess and mottle has the advantage of simplicity but makes measurements relatively insensitive to certain PQ problems such as ink coalescence in inkjet printing.[10] We have found that an alternative approach of using variable tile sizes can reveal important detail about the size scale of non-uniformities. When using variable tile sizes, the tile size used in the analysis must be reported with the results.

A number of PQ attributes would also be valuable additions to the standard. Some of these are likely to result in future ISO-13660 addenda.[6,7]

A definition of line position, for example, would be helpful. Line position is used extensively in diagnostic PQ measurements such as determining the straightness of inkjet nozzles.[11]

Also helpful would be a definition of banding. Banding is a significant problem in most printing processes, occurring in both periodic (sinusoidal) and non-periodic (impulse) modes. [12] Defined PQ attributes for both would be very advantageous.

In addition, a logical extension of ISO-13660 would be the inclusion of color measurements such as intercolor bleed, and color registration and image noise (non-uniformity) in halftones.

Application of ISO-13660

The value of a PQ standard is borne out in its application, as illustrated in some recent studies.

In the world of inkjet printing it is well known that media type significantly impacts print quality, as discussed in the literature.[13] In the following example, a commercially available desktop inkjet printer was used to test raggedness values on six types of inkjet media. The measured raggedness values, based on the ISO-13660 definition, showed marked differences among the different media types, as seen in Fig. 2. The plain paper produced average edge raggedness as great as 20 µm whereas glossy film produced raggedness of only about 8 µm.

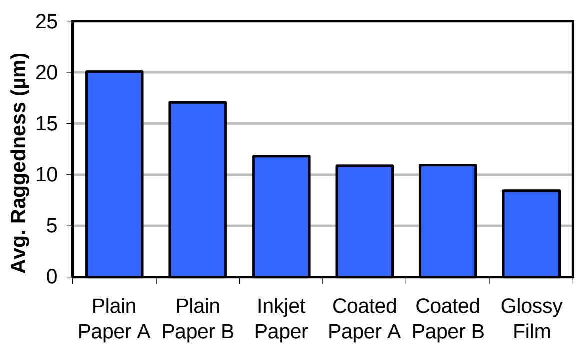

Figure 2: Average line edge raggedness measured on different inkjet media samples. (line length = 4 mm, low-pass filtered at 42 µm)

With further analysis of the data, it was determined that the raggedness of the lines was highly correlated to line orientation, horizontal vs. vertical, as shown in Fig. 3. There was little apparent media effect in the vertical lines. The media effect in the horizontal lines, however, was pronounced, ranging from 22 µm on plain paper to 1.5 µm on glossy film. The disparity in edge raggedness between horizontal and vertical lines was traceable to poor dot placement by the inkjet printer, as shown in Fig. 4, which masked the media effect in the vertical lines.

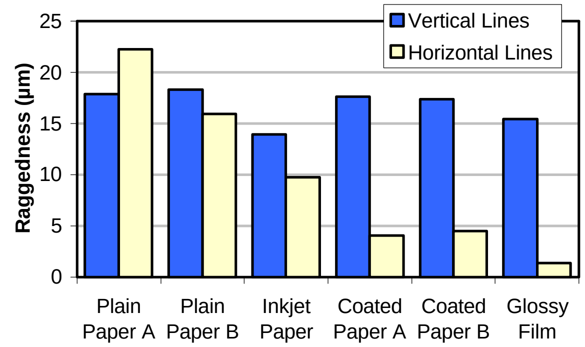

Figure 3: Effect of line orientation on line edge raggedness. (line length = 4 mm, low-pass filtered at 42 µm)

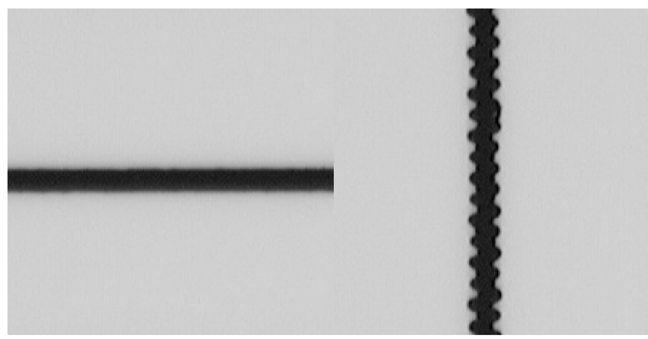

Figure 4: Horizontal (left) and vertical (right) black lines printed on glossy film. Image size is 4.4×2.2 mm

A tremendous amount of information was generated in this investigation. However, in the absence of communicable standards these results would not necessarily be meaningful beyond the limits of the study.

Raggedness is a basic attribute – but exactly what is it? ISO-13660 spells it out: raggedness is the geometric distortion of an edge from its ideal position. It is measured as the standard deviation of the residuals from a line fitted to the edge threshold of the line under study, calculated perpendicular to the fitted line. The definition provides a meaningful terminology for discussion, and the measurement method ensures that the data can be communicated. With refinements such as those suggested above – i.e., a limit on the fineness of the sampling and an upper bound on the sample length – the technique will become very robust.

Further, ISO-13660's requirement that instruments be calibrated to physical units has been shown in recent studies to be critical for ensuring reproducible results. When uncalibrated (e.g., GSV) units are used, the same test conditions can give rise to significant measurement discrepancies, due to such factors as variations in media brightness or the aperture setting in the optics. This can have major ramifications for printing product manufacturers. With instruments calibrated to physical units, results such as those shown in Figs. 2 and 3 can be taken at face value and used as a reliable basis for decision making.

Conclusions

The need for a universal print quality standard has been felt in the printing industry for a long time. Without a standard, questions can be raised about every aspect of a PQ measurement, from the definition of the attribute to the measurement techniques and instrumentation used. ISO-13660, the new international standard for print quality evaluation is about to be released and promises to shift the focus of debate to product performance, where it belongs.

The standard defines fourteen PQ attributes and specifies techniques for measuring them. As the most comprehensive available standard of its kind to date, it promises major benefits for all aspects of the printing industry, from basic research to marketing, by providing a framework for communication industry-wide. In its current state, the standard represents a critical first step. Enhancements and additions will follow as the standard is widely adopted and applied.

Widespread adoption, however, depends on its general availability in PQ analysis systems used by the industry. In another important first step, ISO-13660 has now been incorporated into the software of a commercially available automated PQ analysis system. Intensive use of this system to study a wide diversity of applications has amply demonstrated the importance of ISO-13660 for ensuring that studies of printing products are well controlled and communicable.

References

1. E. N. Dalal, et al., "Evaluating the Overall Image Quality of Hardcopy Output," Proc IS&T's PICS, May 17-20, 1998, pp 169-173
2. P. Engeldrum, "The Image Quality Circle: An Image/Print Quality Management Framework," IMI Print & Image Quality Conference, May 6-7, 1996
3. ISO 2813:1994 Paints and varnishes– determination of specular gloss of non-metallic paint films at 20 degrees, 60 degrees, and 85 degrees, International Organization for Standardization
4. CIE 1931, International Commission on Illumination, Proc 8th Session, Cambridge, England 1931, Bureau Central de la CIE, Paris, 1931
5. ISO/IEC DIS 13660 Draft International Standard, "Office Equipment – Measurement of image quality attributes for hardcopy output – Binary monochrome text and graphic images," International Organization for Standardization, ISO/IEC JTC1 SC28, 1996 (final version to be released)
6. M. Yuasa and P. Spencer, "NCITS-W1: Developing Standards for Copiers, Printers and Other Office Equipment," Proc IS&T's PICS Apr 25-28, 1999, pp 270-273
7. P. Spencer, "IS 13660 New International Standard: Measurement of Image Quality Attributes for Hardcopy output–Binary monochrome text and graphic images," IMI 2nd Annual Print and Image Quality Conference, May 5-6, 1997
8. Company and product information available online at www.qea.com
9. J. R. Hamerly and R. M. Springer, "Raggedness of Edges," J. Opt. Soc. Am., Vol 71, No.3, 1981, pp 285-288
10. N. Jones, et al., "Characterizing and Modeling Coalescence in Inkjet Printing," Proc IS&T's NIP14, Oct 18-23, 1998, pp161-166
11. D. J. Forrest et al., "Print Quality Analysis as a QC tool for Manufacturing Inkjet Print Heads," Proc IS&T's NIP14, Oct 18-23, 1998, pp 590-594
12. Y. S. Ng, "Visual Tolerance Study with One-Dimensional Periodic (Sinusoidal) and Non-Periodic (Impulse) noise in Electrophotographic Gray Level Halftones," Proc IS&T's 11th International Congress on Advances in Non-Impact Printing Technologies, Oct 29-Nov 3, 1995, pp.493-496
13. M. K. Tse and A. H. Klein, "Automated Print Quality Analysis in Inkjet Printing: Case Study Using Commercially Available Media," Proc IS&T's NIP14, Oct 18-23, 1998, pp 167-171