Standardization of Perceptually Based Image Quality for Printing Systems (ISO/IEC JTC1 SC28 and INCITS W1.1)

Eric K. Zeise[1] and Norman W. Burningham[2]
[1]Nexpress LLC. Rochester, New York
[2]Hewlett Packard Co., Boise, Idaho

Abstract

With the single exception of ISO 13660,[1] there are no generally accepted international standards for describing the image quality of printing systems. ISO 13660 provides simple guidelines for the quantitative measurement of many aspects of image quality for binary, monochrome, printing systems, and has had a significant impact in the printing industry. However, as in most measures of imaging system performance, the visual significance of a measurement difference is not addressed in ISO 13660. This weakness prevents a truly meaningful comparison of printing system specifications. To address this weakness, and to provide evaluation methods applicable to more capable systems incorporating gray-level and full-color imaging technologies, INCITS W1, the U.S. representative of ISO/IEC JTC1/SC28, has been chartered to develop an appearance-based image quality standard.[2] This paper will describe the objectives, the development process, the current status, and the results achieved so far by the many contributors to the development of this standard.

Introduction

Since the printed page, or output image, is the product of a printing system, the quality of this image is an important factor to the manufacturers, users and evaluators of printing systems. Most printer users, and even some magazine reviewers of printers, have little knowledge of what image quality is or how to measure it. Misleading terms such as "600 DPI (dots-per-inch) quality" abound.

At present, there are no generally accepted, international standards for specifying image quality with the single exception of ISO 13660. ISO 13660 contains a set of very easily implemented measurement methods for a number of binary, black&white, print quality character-istics. For simplicity, ISO 13660 does not address the perceptual importance of its objective measurements; the visual importance of, for example, 20 granularity units vs. 30 granularity units is not specified. Even with its limited scope, ISO 13660 has had a significant impact on the printing industry, indicating a serious need.

ISO/IEC JTC1/SC28, the standardization committee for office equipment, of which INCITS W1 is the United States representative, voted in September 2000 to charter INCITS W1 with the responsibility of drafting a proposal for an international standard for the evaluation of printer image quality that is appearance based and applicable to more capable systems incorporating gray-level and full-color imaging technologies. This standardization project, INCITS W1.1, is complementary to ISO 13660. In scope and sophistication, this standard will be more extensive than ISO 13660, utilizing robust and capable metrics related to human perception that are applicable to the evaluation of monochrome and color, binary and gray-level printing systems. The image quality measurement tools of this standard will provide a fair, reliable, and perceptually meaningful basis for comparison of printing system characteristics that users, reviewers and manufacturers can use to compare, evaluate and describe competitive products.

The perceived quality of a printed image is governed by the visual characteristics of the image, not by material or engineering specifications. Examples of these visual characteristics are sharpness, color rendition and graininess. These visual characteristics are related to objective metrics by vision models and through psychometric scaling. These connecting relationships give information on how changes in the magnitude of the objective metric affect the visual characteristic. Various visual character-istics of an image can be combined into broad-based attributes that characterize perceived image quality.[3,4]

This standard addresses three vital elements in quantifying perceived image quality:

1) Precisely defined measurement procedure(s) for objective image quality metrics. The metrics will be appearance-based rather than technology-based. They will quantify how the image appears on the printed page.
2) Test images from which the defined measurements can be obtained.
3) Determination of the correlation of the clearly defined and measured attributes with visual assessment. This part of the work provides technical validation for elements (1) and (2).

Development Process

The overall work of W1.1 has been divided among several task teams, each of which will focus on one or two major attributes. This work is being conducted in a manner that ensures that the developed standards are comprehensive and suitable for comparisons of print quality independent of printing technology or engineering parameters or material characteristics.

The overall process to be applied for each major attribute is as follows:

A) Define the attribute and sub-attributes being studied, clearly and unambiguously.
B) Design platform-independent digital test targets suitable for characterizing all aspects of the attribute.
C) Produce hardcopy samples of the test targets that encompass the relevant printing technologies and the relevant levels and types of defects related to the attribute.
D) Measure each hardcopy sample (and/or digitize into other suitable representation for analysis, such as a digitized raster image).
E) Develop computational analysis procedures for objective evaluation of measurements, or other representations, created from the hardcopy samples.
F) Apply the objective measures on the digitized images, or other representations, created from the hardcopy samples.
G) Establish quantitative, subjective quality scales of the attribute for each hardcopy sample through psychometric scaling experiments.
H) Correlate the outputs of the subjective quality scales (Step G) and the objective measures (Step F). If they do not correlate well, repeat steps E, F and G.
I) Independently confirm the validity of the procedures for objective metrics by repeating steps C, D, F and G, using an additional, independent set of hardcopy print samples.

The outcome of this process is the creation of an appearance-based metric that quantifies the visual significance of an attribute through correlation of an objective measure of that attribute with a psychometrically derived quality scale for that same attribute.

Task Teams and Development Status

Substantial progress has been made in development of the W1.1 Standard as of 1-July-2002. For each of the task teams, the contributors to this process, the identified attributes and sub-attributes required to comprehensively describe the appearance-based image quality of printing systems, and the current development status towards quantifying these appearance-based attributes are summarized here.

Text and Line Quality:
Edul Dalal (Xerox, chair), Allan Haley (Agfa Monotype), Paul Jeran (HP), Dale Mashtare (Xerox), John Briggs (QEA), Ted Bouk (Kodak), Mark Robb (Lexmark), David Spencer (SpencerLab), Frans Gaykema (Oce).

Text Quality Attributes (Step A):
- Text character purity: (sharp and smooth edges, freedom from visible voids and breaks)
- Text character fidelity: (visible faithfulness of the characters to the intended shape)
- Text uniformity: (perceived uniformity of the text weight)
- Text color: (proper color, density or contrast to background contrast between styles)

Line Quality Attributes (Step A):
- Line purity: (sharp, smooth and parallel edges, freedom from visible voids and breaks)
- Line fidelity; (visible faithfulness of the line to the intended type and shape)
- Line color: (proper color, density or contrast to background)
- Line weight progression: (visually smooth progression of line weights)

Test Target Creation (Step B):
- A proposed Text Quality test target is being prepared by Allan Haley and Mark Robb.
- The attributes of a Line Quality test target have been agreed upon. A PDF implementation is in preparation.

Macro-Unformity:
Rene Rasmussen (Xerox, chair), Marguerite Doyle Lexmark), Steve Korol (Xerox), Bill Kress (Toshiba), Yee Ng (Nexpress), Ina Eckerleben (Oce), Jodi Walsh (Lexmark), Dave Wolin (ImageXpert).

Macro-Uniformity Attributes (Step A):
- Color uniformity (variations in hue, saturation, lightness, separately or in combination)
  Contributors such as: streaks, bands, mottle, gradients, moire, etc.
- A single overall measure will need to be developed as well as measures for individual contributors to non-uniformity.

Test Target Creation (Step B):
- Designed and created in PDF form (initially only neutral (K) and blue (C+M) versions). Target lightness values have been set at L* = 80, 60, 40 as well as 100% K for black, and L* = 80, 60 as well as 100% CM for blue.
- To account for variations of printer rendition, the test patterns have been implemented with a large set of coverage percentages, and the print procedure ensures that the target L* values are met within specified limits.

Test Target Printing (Step C):
- So far, 5 sets of print samples have been collected.

Sample Measurement (Step D):

- In order to address scanner color calibration to digitize printed targets, we have selected a test target that will be printed as part of the printing procedure and a method for calibrating a scanner using measurements of the test target.

Analysis (Step E):

- Initial evaluation of analysis methods for characterizing macro-uniformity is starting using sample scans.

Micro-Uniformity:

Robert Zeman (Kodak, chair), Rene Rasmussen (Xerox), William Kress (Toshiba), Paul Kane (Kodak), George Chiu (Purdue), Eric K. Zeise (Nexpress), Steve Korol (Xerox), Marguerite Doyle (Lexmark), Terry Nelson (HP).

Micro-uniformity attributes (Step A):

- Color uniformity (variations in hue, saturation, lightness, separately or in combination)
  Contributors such as: streaks, bands, voids, mottle, granularity, textures, noise, etc.
- Field of view is restricted to 25 mm. square (>0.04 cy/mm) to complement macro-uniformity measures.

Test Target Creation (Step B):

- The flat field test targets designed by the Macro-uniformity sub-group will be used.

Test Target Printing, Measurement and Analysis Method (Steps C, D, E):

- Technologies to be included and investigated are: inkjet, electrophotography, silver halide and thermal dye/wax transfer.
- A spectrogram-like analysis techniques to preserve phase information will be used for analysis. Two team members submitted non-proprietary analysis code written specifically for this task. The code is under evaluation.
- Five sets of samples have been printed on inkjet systems, one set on a thermal system, four sets on electrophotographic systems and one set on a digital silver system.
- The scanner calibration method proposed by the macro-uniformity team will be utilized in measurement of these samples.
- We are currently evaluating scans of these samples using the proposed evaluation method.

Gloss and Gloss Uniformity:

Yee Ng (Nexpress, chair), Norm Burningham (HP), Dale Mashtare (Xerox), Margurite Doyle (Lexmark), Jeff Wang (Nexpress), Chung H. Kuo (Nexpress), Eric Schneider (HP), Ted Bouk (Kodak), John Kesslar (Paxar Corp., TAG member SC31).

Gloss Attributes (Step A):

- Gloss value
- Within page (flat-field) gloss uniformity
- Page to Page (flat-field) gloss uniformity
- Differential Gloss
- Gloss Artifacts

Test Target Creation (Step B):

- Defined "W1.1 Differential Gloss Test Chart" (40 color patches measurable using multiple gloss measurement geometries (20° -> 85°)).
- Defined "W1.1 Gloss Uniformity Test Chart" (created using a triangulation method with anchor patches and patches that are more sensitive to gloss changes (from round-robin Differential Gloss data)).
  Sample Printing and Measurement (Steps C, D):
- Completed a round-robin study of the objective measurement of the Differential Gloss attribute involving 19 paper/technology combinations covering a wide range of gloss values measured at 20, 45, 60, 75 and 85 degree measurement geometries.
  Analysis Method and Analysis (Steps E, F):
- We have established a "Standard Deviation vs. Gloss value" curve based on all 19 paper/technology combinations for 20, 60, 75 and 85 degree geometries.
- Gloss measurements made by different teams on the same print using gloss meters made by the same manufacturer agree with each other well for the measurement geometries tested.
- Although gloss measurements are consistent within a given measurement geometry, there are significant inconsistencies when measurements of one geometry are charted against measurements at a different geometry.
- Gloss measurements of the same print using gloss meters of the same stated geometry, but different manufacturers, show significant deviations except at the two ends of the gloss range where the devices lose sensitivity.
  Psychometric Scaling (Step G):
- We have completed a psychometric scaling experiment defining the threshold just noticeable difference of nearly adjacent gloss samples as a function of overall gloss.

Color Rendition:

Bob Cookingham (Kodak, chair), Edul Dalal (Xerox), Susan Farnand (Nexpress), Jason Gibson (HP), Bill Kress (Toshiba), Karin Topfer (Kodak), Oscar Martinez (HP), Norman Burningham (HP).

Color Rendition Attributes (Step A):

- Color Fidelity: Colors look correct (does not necessarily imply color matching)
- Color Scale: Colors that should be perceived as separate are distinguishable.
- Color Continuity: Colors that should be perceived as smoothly varying are free of contouring.

Test Target Creation (Step B):

- We have selected the color quantization sub-attribute as the first sub-attribute for evaluation.
- We have chosen a set of sweeps using 8 colors (C,M,Y,R,G,B with sky and skin-tone included).
  Test Target Printing and Measurement (Steps C, D):

- We have scanned samples of these targets that were rendered on photographic and electrophotographic printers.
- An initial color quantization analysis method has been tried.

  Analysis Method and Analysis (Step E):
- We are currently evaluating these scanned samples for color quantization, tuning the target design and studying analysis methods.

Effective Resolution: (Established May 2002)

Norman Burningham (HP, chair).

Membership is being solicited.

Summary

The need for a standardized method for printer image quality evaluation that provides a perceptually meaningful measure of quality differences is being met by ISO/IEC JTC1/SC28 through the development effort chartered within INCITS W1 by international ballot in December 2000. This standard will provide a complementary capability to the existing ISO 13660 image quality evaluation standard, with perceptually scaled measures of image quality. The standard methodology will provide a fair, reliable, and perceptually meaningful basis for comparison of printing system characteristics that users, reviewers and manufacturers can use to compare, evaluate and describe competitive products. An initial draft of this standard is planned for completion by year-end 2002. Interested parties who can help develop this standard are encouraged to contact the authors.

References

1. ISO/IEC 13660, "Measurement of image quality attributes for hardcopy output – Binary monochrome text and graphic images" (2001).
2. "NCITS-W1: Developing Standards for Copiers, Printers and Other Office Equipment", Mashiho Yuasa and Paul Spencer, IS&T 1999 PICS Conference, Savannah, Georgia.
3. "Evaluating the Overall Image Quality of Hardcopy Output", Edul N. Dalal, D. Rene Rasmussen, Fumio Nakaya, Peter A. Crean and Masaaki Sato, IS&T 1998 PICS Conference, Portland, Oregon.
4. "Status of the Development of International Standards of Image Quality", Norman Burningham and Edul Dalal, IS&T 2000 PICS Conference, Portland, Oregon.

Biography

Eric K. Zeise is a research associate and group leader for image quality evaluation at NexPress LLC in Rochester, N.Y. He holds 17 patents in the areas of systems modeling, printing systems architecture, and perceptual image quality. He joined the research laboratories of Eastman Kodak Co. in 1981, after receiving a Ph.D. in low-temperature physics from Cornell University, and became an initial staff member of Nexpress LLC when it was formed as a joint venture between Eastman Kodak Co. and Heidelberger Druckmashinen AG in 1998. He is active in standards development and is project editor for the ISO/IEC SC28 & INCITS W1.1 team developing perceptually based image quality measures for printing systems.

Norman W. Burningham is a senior engineer/scientist responsible for applying concepts of quantitative image quality in printer products development at Hewlett Packard Company in Boise, Idaho. He holds a Ph.D. in Chemical Engineering. He has been active in both U.S. national and international standards bodies and was the initial organizer and project editor of the INCITS W1.1 standards development activities.