Extensive Works of ISO/IEC 13660 and the Current Status (ISO/IEC JTC1/SC28 and JBMIA SC28/WG4)

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Abstract

ISO/IEC 13660: 2001 provides basic definitions of image quality attributes for binary, monochrome hardcopy outputs, and it has a significant impact in the office equipment and printing industry. However, calibration (tonal, spatial, resolution, and so on) instructions for measurement instruments such as image scanners, or compliance test charts for the instrument and image data for the algorithm of measurement software and goal values for each attribute are not addressed or prepared sufficiently in this standard. JBMIA (Japan Business Machine and Information System Industries Association) SC28/WG4, the Japanese representative of ISO/IEC JTC1/SC28, has been involved in the development of the standard from the beginning, and has continued the extensive works for developing those additional materials in order to enhance the usability of the standard. This paper will describe the objectives, the developing process, the current status and the future works to extend it to color images.

Introduction

The international standards to systematize the image quality attributes for hardcopy outputs, which correlate with human perception of print quality, and to specify methods by which those image quality attributes can be measured automatically with simple measuring equipments have been developed in ISO/IEC JTC1/SC28.[1] As a first step, "Measurement of image quality attributes for hardcopy output - Binary monochrome text and graphic images" has been standardized as ISO /IEC13660.[2] It defines eight image quality attributes of the character and line image of binary monochrome and six image quality attributes of large area image as well as the measuring methods. ISO/IEC 13660 requires a compliance test of a measurement system, since it specifies a method of directly measuring the characteristics of the image itself without specifying test charts or reference images. However, only the compliance test method for image quality attributes of lines and the goal values for the test chart are specified in ISO/IEC 13660, and there is no similar description of large area image quality attributes at all.

Accordingly, the JBMIA SC28/WG4 proposed a New Work Item titled "ISO 13660 Addendum on System Compliance Test Chart" to add compliance test image specifications and goal values for large area quality attributes. WG4 prepared a highly accurate chart to specify the goal values as shown in Figure 1.[3-4]

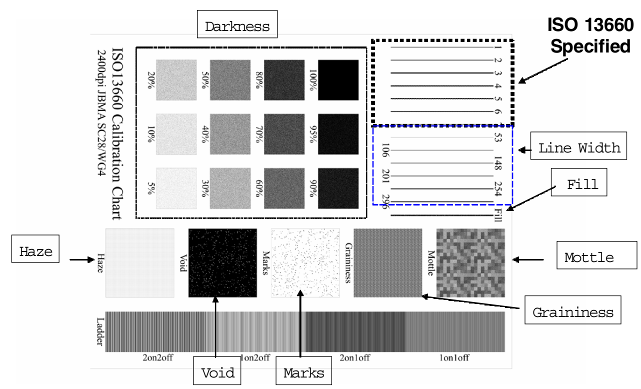

Figure 1. Additional patterns to System Compliance Test

Problems of ISO/IEC 13660

SC28/WG4 set up the goal values for the system compliance test of each attribute (Table 1), according to the value given by the average ± standard deviation value from the measurement system of each SC28/WG4 participating company through the use of the test chart, and proposed a WD (working draft) to SC28, in order to enhance the usability and availability of ISO/IEC 13660.

The WD was then approved; however, the range of the goal values was too wide as shown in Table 1, since variations among measurement systems were large.

Accordingly, SC28/WG4 determined the procedures for enhancing the usability and availability of ISO/IEC 13660 as shown in Figure 2. According to these procedures, investigation of the variations in measured values among different scanners, verification of each measurement algorithm, and investigation of the correlation between a measured value and subjective evaluation value were carried out.

Table 1. Goal Values for Line Attributes

Line	Darkness (density)	Raggedness Left Side (micrometers)	Raggedness Right Side (micrometers)
1	0.75 - 1.06	0 - 10	0 - 10
2	0.98 - 1.28	0 - 10	0 - 10
3	1.11 - 1.37	0 - 10	0 - 10
4	0.68 - 1.19	29 - 43	17 - 32
5	1.06 - 1.32	26 - 41	24 - 38
6	0.92 - 1.21	5 - 16	8 - 16
7	0.72 - 1.02	10 - 19	6 - 16

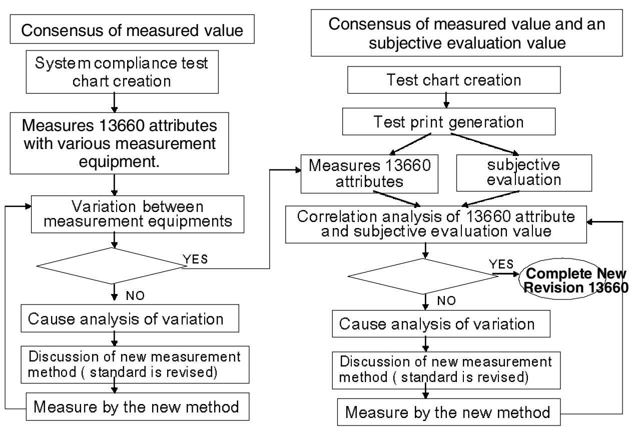

Figure 2. Approach to improve ISO/IEC 13660

In order to investigate the correlation between the subjective evaluation and measured value by use of ISO/IEC 13660 algorithm, SC28/WG4 produced the following samples since the sample space in the compliance test chart was too narrow:

1. To investigate the correlation between the measured value and subjective evaluation value in terms of blurriness and raggedness, 43 kinds of line patterns were printed with four printers in three different marking methods of ink-jet, silver halide and xerography. The ink-jet prints were printed on two kinds of paper (special-purpose paper and plain paper).
2. To investigate the correlation between the measured value and subjective evaluation value in terms of mottle and graininess, 18 kinds of large area patterns were respectively printed with four printers.

The results of print-sample measurements are shown in Table 2.

The samples for subjective evaluation were selected as follows:

Blurriness: 14 kinds (2 printers x 7 patterns)
Raggedness: 26 kinds (2 printers x 13 patterns)
Mottle: 20 kinds (Grade: 0, 0.5, 1, 2 and 3)
Graininess: 20 kinds (Grade: 0 to 4)

Table 2. Measurement Results

No	Attribute	Measurement Results
1	Line Darkness	It varies slightly on the high-density side.
2	Line Width	It is correct in the 100- to 800-•m range.
3	Blurriness	It is mostly in agreement between two companies. For the other two companies, the value is slightly lower.
4	Raggedness	For only one company, it is one-half the value of the other companies.
5	Contrast	Variations are a somewhat large.
6	Fill	No discussion is available about the samples at this time, although the values of each company are inconsistent.
7	Darkness	It is slightly higher in the high-density area (> 2.0) for one company. It agrees with the values of the other companies.
8	Mottle	It agrees except for one company.
9	Graininess	It agrees except for one company.

The following five steps impairment scales were used for the subjective evaluation:

5. *X* is imperceptible.
4. *X* is perceptible but not annoying.
3. *X* is permissible although slightly annoying.
2. *X* is impermissible.
1. *X* is impermissible at all.

where, *X* is replaced with blurriness, raggedness, mottle, or graininess.

The observers of subjective evaluations were comprised of 16 non-engineers from SC28/WG4 participating companies.

The correspondence between the subjective evaluation ratings and the ISO/IEC 13660 measured values was given as follows:

- For both raggedness and blurriness, the results are considerably in agreement. However, since this is achieved only with the methods of xerography and ink-jet, it is unknown how the results will be if silver halide is added.
- The results of the xerographic sample deviates from the others due to the gathering of high frequency components. The size of averaging should be enlarged, or a correction with a visual transfer function and whatnot should be added.
- For mottle, the results are different between xerography and ink-jet. The subjective evaluation was carried out only regarding the attributes of mottle, while in the physical measurement, any attributes other than mottle was also included.
- The average physical value of each company was used as the ISO/IEC 13660 measured value. The variation of the measured values of each company is comparatively large.

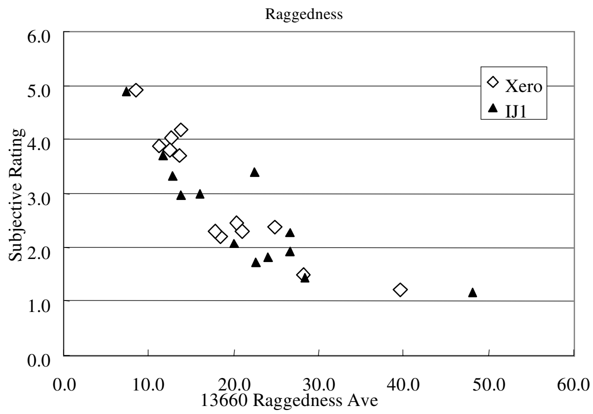

Figure 3. Raggedness

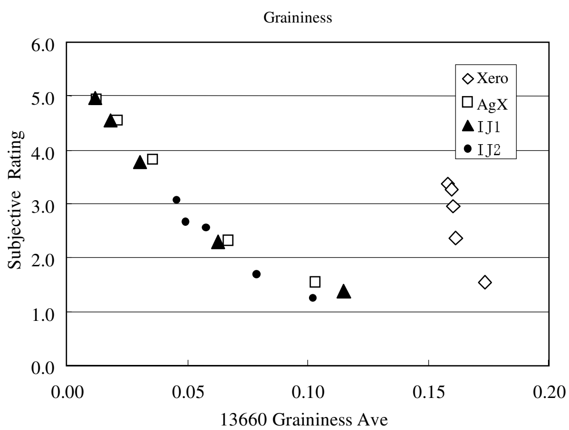

Figure 4. Graininess

With the results shown above, the following three items are listed as problems:

A) Calibration methods need to be added, in order to reduce the variations in measured values.
B) The standard digital data is required, in order to verify the measurement algorithm.
C) The algorithms of the attributes with low correlation between the subjective rating and measured value should be reconsidered. Especially, reconsideration should be made for mottle and graininess.

Consideration of Image Scanner Calibration Method

Calibration for each of the measurement algorithm and image scanners should be required in order to reduce the variations in the ISO/IEC 13660 measured values. For the algorithm, the operation check can be made through the use of digital image data. On the other hand, a chart is required for the calibration of image scanners. The existing compliance test chart has excessively limited targets for this purpose, so the scanner calibration procedures and calibration chart are considered. As necessary characteristic items for the calibration, the resolution, tone, dynamic range, consistency within a page, and time fluctuation were considered. In addition, the method of converting resolution, method of converting a reflectance to density, backing material, presence / absence of gloss of the chart, etc. were considered for other items that should be determined. Other items in which colorization will be pursued in the future were also considered.

Image Scanning Conditions

Basically, the ISO/IEC 13660 measurement conditions are followed. In the case where an automatic adjustment of a scanner functions with a normal use, turn off the function wherever possible. In addition, for scanners that are susceptible to the ambient temperature and those that require warm-up periods, prepare those scanners in such a manner that they can perform in a stable condition.

- Signal: 8-bit output for each color (RGB)
- Scanning resolution: 600 dpi
- Gamma correction: Use the same gamma value as the ISO/IEC13660 measurement, and specify it.
- Dynamic range correction: OFF
- Sharpness correction (filter etc.): OFF
- Test Chart placement: Place it in the same location as used in the ISO/IEC 13660 measurement.
- Backing Material: The backing of each chart shall be in white.

Tone Reproduction

Test Charts

As an ideal chart, it is desirable to satisfy the following conditions:
Number of tone steps: Approx.15 – 16 steps
Maximum density: 1.9
Minimum density: 0.06 or less
Particularly, Kodak paper (gray scale 8x10 in.) was used.

Measurements

1. Place the chart in such a manner that scanning can be performed from the chart white area, and perform scanning.
2. Obtain the green channel output value by averaging the values in a square area of 12.7 mm x 12.7 mm at three locations (areas 2 cm away from each end and the center) for each tone of the chart.
3. Using the obtained output values of the green channel and the data of pre-measured density and reflectance, obtain the relationship between the sensor output value and the density / reflectance.

Resolution

Test Charts

The array patterns of line space with 2, 3 or 5 lines/mm are required, but a type of evaluation method to be adopted becomes a problem in addition to the patterns. For example, when evaluation is carried out with contrast, the phase exerts an influence on measurement depending on the moiré fringes and chart location. It is also conceivable to transfer a scanned image to the frequency domain with an FFT and to evaluate resolution of a scanner with the peak wavelength and its amplitude. Accordingly, it was decided to use the A4 ladder chart made by Fuji Color Service Co., Ltd. and adopts both the contrast and FFT analysis as the evaluation method.

Measurements

1. Place the chart in such a manner that the pattern of 8 lines/mm can be located on the left side, and perform scanning.
2. Carry out the following measurement regarding the three locations of each ladder pattern:
   a. Carry out segmentation (22 mm in a direction perpendicular to the ladder line and 0.5 mm in a direction horizontal to it). Converting output values of the green channel to their reflectance, and averaging the values in the 0.5 mm short side direction obtain the reflectance profile. Evaluate the contrast based upon the maximum and minimum reflectance values, through the reflectance profile.
   b. Carry out segmentation (area of 22 mm x 22 mm). Convert green channel output values to their reflectance values, perform a two-dimensional FFT, and carry out averaging for each frequency.

Variations within a Page

For variations within a page, both the sensor output value variations and the position accuracy evaluation were investigated

Output Value Variations

Test Charts

Fuji Color Service A4, uniform density plate 0.5D

Measurements

1. Place the chart in such a manner that scanning can be performed from the chart white area, and perform scanning.
2. Obtain the green channel output value by averaging the values in a square area of 12.7mm x 12.7mm at three locations for each tone of the chart.
3. Using the obtained green channel output values and the data of pre-measured density and reflectance, obtain the relationship between the sensor output value and the density / reflectance.

Position Accuracy

Test Charts

Grid distortion chart made by Edmund Optics, Inc.
(Dot-to-dot position accuracy: ±8µm)

Measurements

1. Place the chart so as to minimize the likelihood of tilting, and perform scanning.
2. Measure the X and Y coordinates of the dot centers on the remaining three corners with respect to the dot center on the upper-left corner and then calculate the distances between the dot centers.

Color Reproduction

Test Charts

As the color reproduction evaluation chart, the IT8 chart for the scanner calibration was used, since charts with screen structure and fluorescent-component laden charts are not desirable. However, since the size of the color chart was small, the A4 size custom-made product (enlarged reflection type IT8 target) made by Fuji Photo Film Co., Ltd., on which IT8 was printed, was used.

Measurements

For the evaluation method, further consideration should be continued.

1. Obtain each channel output value of the RGB by averaging in a square area of 5 mm x 5 mm for each patch in the order of measurement by line from A1 to L22.
2. Enter the values in the table of correlation with the measured values of each patch.

Results of Scanner Characterization

The grasped examples of characteristic of seven scanners with each different model provided by five companies are shown below. The measurement examples of the tone and resolution are shown in Figure 5 and 6.

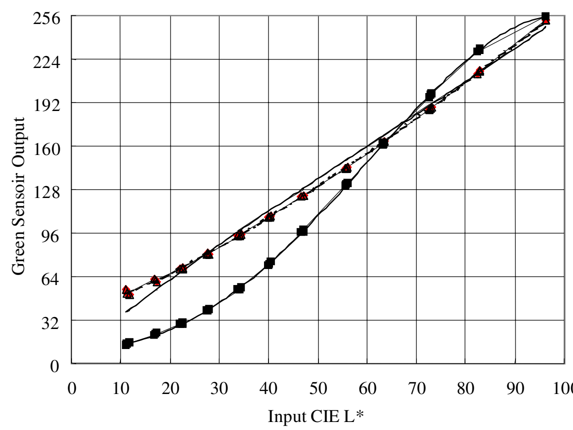

*Figure 5. Changes in Sensor Output Values Versus Input CIE L**

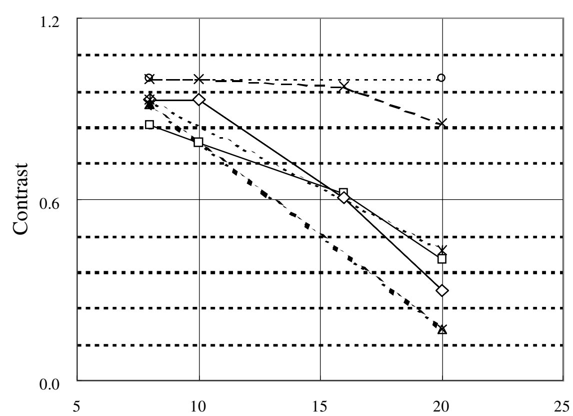

Figure 6. Contrast

For the tone reproduction, the scanner output signals tend to become linear against L*. Since the ISO/IEC 13660 is assumed on the linearity of output signals versus reflectance, the standard descriptive method needs to be reconsidered in some cases.

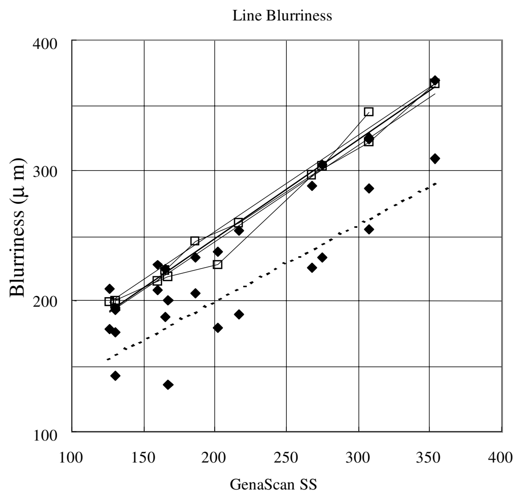

Figure 7. Blurriness

In addition, the blurriness results calculated by the ISO/IEC13660-measurement algorithm are shown in Figure 7. Since those results indicate a trend toward strong dependence of the scanner resolution shown in Figure.6, it is required to reconsider blurriness from both viewpoints of the measurement calibration method and algorithm.

Future Work

The guidelines and requirements for selection of image scanners will be established according to the results of the scanner characterization experiment. In addition, the algorithm verification image data will be prepared, and the target values for each attribute will be set up.

The following items will be revised or added to the ISO/IEC13660-revised edition by incorporating the results above.

6 **System compliance**
6.1 Compliance standard
6.2 Instruments
6.3 Test objects
6.3.1 Specification for production of lines 15
6.3.1.1 Line set 1
6.3.1.2 Line set 2
6.3.1.3 Line set 3
6.3.2 Specification for production of large images
6.3.2.1 Mottle pattern
6.3.2.2 Graininess pattern
6.3.2.3 Extraneous marks pattern
6.3.2.4 Voids pattern
6.3.2.5 Background haze pattern
6.3.2.6 Large area darkness pattern
6.3.2.7 Array pattern of line space
6.4 Goal Values

Annex D A layout of test images for system compliance test
Annex E Image Scanner calibration guide
Annex F Measurement algorithm verification by image data

Conclusion

It was required to reduce the variations in measurement values among measurement systems and to improve the degree of agreement with the subjective evaluation. Accordingly, the JBMIA SC28/WG4 pursued the investigation activities regarding the agreement between the subjective evaluation and the variations in measurement values according to the ISO/IEC 13660. This paper revealed that reducing the variations in measurement values require the addition of calibration methods to the standard as well as the standard digital data for measurement algorithm verification, and that the attributes with low correlation between the subjective rating and measured value require reconsideration of the algorithms.

We plan to implement activities to fundamentally resolve the problems above and pointed out in the past [5-7] in cooperation with the international SC28 members.

The JBMIA SC28/WG4 has also considered a color version of the ISO/IEC 13660: NP 19754 "ISO/IEC 13660 Addendum Measurement of Image Quality Attributes for Hardcopy Output--Large Area Color Images." We intend to consider this including coexistence with the printer image evaluation standards pursued in the U.S.[8]

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Biographies

Toshihiko Inagaki is image quality research group manager of Research & Development Center of Document Product and Supply Company in Fuji Xerox Co., Ltd. He is chief examiner of WG4 in the Japanese committee of ISO/SC28, and project editor of ISO 13660 addendum on system compliance test and ISO 13660 addendum on measurement of image quality attributes for large area color images. And he is chief examiner of WG1 of technology committee in the Imaging Society of Japan since 1990.

Tsuyoshi Saito joined Fuji Xerox Co., Ltd. with his M.S. degree in Knowledge based Information Engineering from Toyohashi Universal of Technology in 1996. He is a researcher of Research & Technology Center in Document Product and Supply Company, Fuji Xerox. His work has focused on image quality measurement and evaluation system development.

Kazuhiko Uneme received his B.E. degree in Physical Engineering from The University of Electro-Communications in Tokyo in 1982. Since 1982 he has worked in the Business Machines Development Division at Konica Corporation in Tokyo. His work has primarily focused on the process of toner image development and fixing on the media.

Susumu Imakawa received his Master's degree in precision engineering from Shinshu University in 1981. He joined Ricoh Co., Ltd. in 1981. During that time he has been involved in the research and development of laser optical system for laser printer and image quality measurement. He is an active member in the Japanese committee WG4 on ISO/IEC JTC1/SC28.

Kunihiko Sato received his BS and MS degree in Electronic Engineering from Nihon University. He joined Fujitsu in 1984. During that time he has been involved in the development of new printing processes and measurement technologies include print quality. He joined Fuji Xerox in Feb. 2003.

Nobuyasu Ogata joined Sharp Corporation in 1982. During that time he has been involved in the development of new printing technologies, print quality measurement and image processing. Currently he is a member of the Product Development Center working to planning for new printing technologies.

Atsuhisa Morimoto received both B.S. and M.S. degrees in the Electrical Engineering and the Computer Science from Nagasaki University, Japan. He joined Sharp Corporation in 1997 and moved to Sharp Laboratories of America, Inc. in 2000. Since 2002 he has worked in the Document Products Development Center at Sharp Corporation. His research interests include image quality predictions and visual modeling.

Satoshi Saito is a staff engineer at Canon Inc. in Susono, Shizuoka. He is active in the development of printer products, print quality measurement.

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