

Image Quality Measurement and Analysis on Color Ink Jet Outputs

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Abstract

Quantitative Image Quality analysis of Ink Jet prints can be applied in business printing, arcs printing, publisher works for the art, home, décor markets, advertising printing, digital proofing, and computer aided industrial design works. Many manufacturers of color Ink Jet printers use the term "photo quality" in estimating of IQ. It is supposed to be excellent, like photograph print quality. However, since this term is not yet defined quantitatively, it may cause misunderstandings and manipulations during evaluation of print quality.

This paper describes quantitative method of analysis of quality of In Jet prints and contains a proposal of comparison a quality of color prints to quality of photo and to human vision. Algorithms of quantitative method of comparison, analysis and measurement of IQ are described.

Algorithm to Compare IQ of Ink Jet color Prints and a Photo

Input to compare of photo and color Ink Jet prints is an electronic file Fo of attributes. ISO/IEC 13660, 5, N 348 and N363 of ISO/IEC JTC1 SC28, 8,9, practical remarks from printers service and references 2,6,7,10,11 describe a definitions and measurement method of IQ attributes. Input file Fo is the electronic form of illustration of these attributes. The same file Fo is an input data to compare of quality of photo and Ink jet prints.

Table 1 shows algorithm of these comparisons.

File Fo of image target is input file to comparison of quality of photo and Ink Jet prints. File Fo is a electronic form of IQ attributes. As software input file Fo was used a color test file from Minolta R&D Center - Toyakawa, Japan.

Description of Algorithm

Comparison of IQ of photo and color prints is made in any steps.

Step 1.

Definition of IQ attributes are described using ISO 13660, IEC 61966, N348 ISO/IEC JTC1 SC28, references 1,2,4, and practical analysis of Ink Jet prints.

Final results of first step are definitions of IQ attributes.

Table 1. Algorithm of comparison of quality of photo and Ink Jet prints-

Definitions of IQ color attributes (according ISO 13660, N238, N363, references)
end results: **definitions**

Input files of IQ attributes Fo
disc file diskette tape cartridge
end result: **file Fo** -electronic format of IQ attributes

Target of photo Pt
(printing of file Fo by image setter, 2400dpi, on photo glossy paper and taking pictures by photo camera, first calibration, requirements)
end result: **target** of photo **Pt**

Targets of Ink Jet prints Pi
(printing of file Fo by different Ink Jet printers, first calibration of printers, own management color system, requirements)
end results: **targets Fi** of prints i=1,2,3 n

Scanning of targets
(by scanner, CCD Camera, microdensitometer, first calibration, requirements)
end results: **photo file Ft** and **files of prints Fi** i=1,2, n

Calculating values of attributes
(using software programs, for example LUCIA)
end results: values of IQ photo attributes **Vt=V(jt)** j= 1,2,3, m "j" represent individual attribute, values of IQ prints attributes **Vi=V(ji)**
Comparing of values of attributes (using software program, for example LUCIA) **Kj=Vji/Vjt** End results: comparison of results **Kj** j=1,2,3, m

Multi-criterion estimating of IQ of prints as function of IQ of photo (by multi-criterion theory, requirements) **Qi=∑Kj Bj** (Bj - balance of attribute) end result: **total IQ of print for individual printers**

Step 2.

Designing of electronic form of IQ attributes- input file Fo. IQ attributes are described as image elements in Minolta's color target. These are: pictures on the paper and in electronic form as file Fo.

Final result of second step is input file Fo.

Step 3.

Design of photo target and print targets.

The target of photo is designed by:

- printing of file Fo use imagesseter, 2400 dpi on photo glossy paper (for example a Kodak glossy paper),
- taking picture by photo camera on photo glossy paper.

The imagesseter should first calibrate, using a color target Agfa F8.

Ink jet prints targets was designed by printing of file Fo by different Ink jet color printers, use:

- own management color system,
- recommended by manufacturer paper (glossy paper).

A printer was first calibrated, sin a color target Agfa F8.

Final results of this step are a photo target (a photo) Pt and a print targets (prints) Pi "i" - representing different Ink Jet printers; i =1,2,3,…….n.

Step 4.

Scanning of targets and design electronic photo target file Ft and prints targets files Fi (i=1,2, 3,…n)

To same use of described scanner (for example HP scanner…. 1200x 1200 dpi). The scanner was first calibrated by using a color target Agfa F8.

Final results of forth step is file of photo target Ft and files of print targets Fi.

Step 5 and 6.

Next steps are: calculate and compare of value of IQ photo attribute Vt=V(jt) and values of IQ prints attribute Vi=V(ji) (j=1,2,3,….m, "j" - representing different attributes).

Comparing of values of attributes is by equation:

$$Kj = Vi / Vt \quad (1)$$

If Kj > 1, he has sign value plus ,
if Kj < 1 he has sign value (1- Kj) and minus.

Final results of these steps are Kj values. (j=1,2,3,….m).

Step 7.

Next step is a estimating of universal quality of image of prints Qi i= 1,2,3,..n "i" is symbol of individual printer.

Estimating is design by use multicriterial theory. Firstly the balance (importance) Bj of each attribute is described.

For example: in color Ink Jet IQ weighty is a value of color gamut ; Bj of color gamut is for example Bcg=1,4; width of line is less weighty and for example Bwl=1; etc.

End has made a sum:

$$Qi = \sum Kj\ Bj \quad (2)$$

for all attributes of individual print of Ink Jet printer.

This sum Qi describes all Image Quality of prints from individual Ink Jet printer.

Final result is total Image Quality of print for individual printer Qi in comparison to IQ of photo.

I understand as photo quality the quality of prints, that has total Qi=1 or more.

Proposed algorithm made possible quantifies compare Image Quality of photo and Ink Jet prints and IQ of two or more printers.

Attributes of IQ: Choice, Definitions, Measuring Methods

Attributes of IQ of color Ink Jet prints contain universals attributes (described on ISO IEC 13660, N348, N363 5,8,9, on references 6,7,10, and specific attributes on Ink Jet prints 2,4,11). By select of attributes take into consideration parameters:

- of color describing : color gamut value (a), optical density of primary colors - CMYK (b), tone reproduction - ΔE ab by DIS ISO 15775 (c);
- of dots attributes: resolution (d), minimum dimension of dot (e);
- of line attributes: blurriness (f), raggedness (g), stepping of line (h), linear resolution (i), line width (k), satellites (l);
- area attributes: banding (m), graininess (n), mottle (o),
- characters attribute; geometric distortion of elements of characters (p).

Choice of attributes is made by:

- Analysis of different Ink Jet prints, different printers and on different papers.

From service remarks is known: any Ink jet printers have difficulties on printing of small characters, peculiarly yellow characters.

Definitions of attributes and these measure methods in majority in standard and references are described. (For example - a-4 c - DIS ISO 15775; b,f,g,k,- ISO 13660; m - N348; n,o -6,7,10; h,i,l - 2.

Optical density of primary colors (b) is measured as optical density of monochrome outputs - by ISO 13660.Resolution (d) and minimum dimension of dots (e) is measured as dimension o black point on with area and white point on black area (from Minoltas target of IQ). Geometric distortion of characters measure is difficult. These investigations are not made. It is a proposal of printing a small characters: black on white area, with on black area, and yellow on white area. (By Minolta's target), and see on the eye. Probably is possibility measuring by using method to estimate of KANII characters 6.

Specific design of test targets Pt (photo target) and Pi (prints targets) by algorithm assures synonymous of design of targets and possibility of they comparison.

Table 2. Algorithm of comparison of results of measurements of IQ attributes of Ink Jet prints and human vision

Input file **Ft - file of photo target** **Fi - files of print target**s
Design of cross-sections: From photo target file and From prints target files
(between points A(x1,y1) and point B(x2,y2) of image for separate attributes "j" **G=G(AB)** G- value from scanner (similar optical density)
End results: **Fjt=Gjt(xy)** function G between AB for attribute j of photo and **Fji=Gji(xy)** function G between AB for attribute j of prints
Transformation of input files Fjt and Fji by human vision theory (for example by Cobras theory)
End result: transformed file **Tjt**=Tjt(xy)for photo file Fjt, and transformed files **Tji**=Tji(xy) for prints files Fji
Design of **Histograms**: Hjt - of IQ photo attributes Hji - of IQ prints attributes **Ht and Hi**
As histogram I understand: Linear cross-section of target element G=f(xy) between points A and B (add. Histogram can bee as function of gray levels)
End results : **histograms**
Comparison of histograms: **Ht ⇔ Hi**
Calculate the difference between Hjt and Hji for individual points (x) and as average difference Km=∑Gjt-Gjt)/number of points or for add. histogram Km=∑Gjt-Gjt)/ 256 and its standard deviation
End result: total difference of photo and human vision **Ktot= ∑Km /m** and its standard deviation for all picture

Comparison of IQ Attributes Value and Human Vision

Files Ft (photo target) and Fi (Ink Jet prints targets) are input files to comparison of IQ attributes and human vision. These files are created in a four-step process of comparison IQ attributes of photo and Ink Jet prints. Algorithm -table 2- is used to comparison of IQ attributes and human vision.

Describing of Algorithm

Files Ft (photo target) and Fi (Ink Jet prints targets) are input files to comparison of IQ attributes and human vision. These files are created in a four-step process of comparison IQ attributes of photo and Ink Jet prints. Algorithm (Fig. 5) is used to comparison of IQ attributes and human vision.

Step 1.

Designing of linear cross-sections from Ft and Fi between points A(x1,y1) and B(x2,y2) for each IQ attribute. (Targets Ft and Fi are composed from individual images, equivalent to individual attributes. Targets were made by MINOLTAS electronic color target from R&D Center - Toyokawa, Japan.

In the first step cross-sections of each individual attribute "j" are made, (j=1,2,3,…m, with "j" representing different attributes). These cross-sections are made from one photo target and many print targets "i" (i=1,2,3,…n; with "i" representing different printers). Cross-sections are made between points A and B, with the same location on a photo target and a print target.

The final results of first step: files:

Fjt= Gjt(xy) for attribute "j" of photo,
Fji= Gji(xy) for attribute "j" of prints,
G - value from scanning (representing optical density from targets CMYK).

Before creating Ft and Fi , scanner should be calibrated using AGFA IT8 color target.

Step 2.

Transformation of Fjt and Fji files using human vision theory. I prefer image histogram modification method by Cobra 3.

I would like to apply Cobra theory in the following way:

As input are files Fjt and Fji as function of value G= G(xy) between points A and B from scanner.

Files Fjt and Fji are transformed into Tjt and Tji using Cobra's quadratic hyperbolisation method, (this is a modified version of Moraine's transformation).

$$T = \frac{Go\ (1 + Go)}{(G + Go)\text{^}2} \qquad (3)$$

Go - value from scanner of background
G - value from scanner of individual points from image

The final results of second step:

files Tjt - transformed files from photo target,
files Tji - transformed files from prints, as function x.y between points A and B.

Step 3.

Designing of histogram Hjt - of IQ photo attributes from transformed Tjt and Hji - of IQ attributes from transformed Ink Jet Tji .

Using Cobra's method histograms Hjt and Hji between points A and B are made.

As histogram I understand a linear cross-section of target element.

Final results of third step: histograms.

Additional histogram (Add. hits.) can be created as number of occurrences of value G as function of gray levels (0,1,2,3,… 255) on Hjt and Hji.

Step 4.

Comparison of histograms: H1t with H1i and H2t with H2i … Hmt with Hmi.

I suggest to calculate the difference between histograms Hjt and Hji as average difference K and its standard deviation:

$$K = \sum(Gjt - Gji)/ \text{ number of points} \quad (4)$$

or (for additional histogram):.

$$K = \sum(Gjt - Gji)/256). \quad (5)$$

(for example:

- points: x1,x2, ….xn or
- (for add. his) gray levels 1,2,3,… 256.

Final results of fourth step: m various differences Km for different attributes.

Final result of the algorithm is total difference Ktot of photo and human vision calculated as average:

$$Ktot = \sum Km/ m. \quad (6)$$

and its standard deviation.

Conclusions

Described method makes possible to quantitatively compare IQ of photo and Ink Jet prints and human vision too. Method makes possible a comparison of IQ of two color prints from two (or more) different printers. The term "photo quality" is being quantitatively defined by the algorithm.

The method by algorithms should be verified by actual measurements.

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