ContRAST.
Evaluation of ink jet print quality. Specific measurement in correlation with visual perception.

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Abstract

Print quality is often assessed visually, particularly in the field of ink jet printing. These human evaluations are sometimes in disagreement and incompatible with one another. The Centre Technique du Papier (C.T.P), which has extensive experience in this field and that of image analysis, has developed a system that is capable of measuring each major print quality criterion for ink jet printing quickly and reliably extracting an overall quality index. This measurement is based on a knowledge of the quality of the ink jet printers available on the market, gained by collecting samples to build up a data base that is constantly being enriched as new developments are made on the one hand in print media and on the other in the equipment used (machines and inks). The system is well suited to carrying out benchmarking surveys.

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ContRAST : Control & Research Automated Sensor Tool.

Introduction

For a number of years now, digital printing, and in particular ink jet printing, has been undergoing significant development. This expansion has not taken place without a constant improvement in processes, media and consumables.

The range of quality achieved with this type of printing is now very wide. It is now possible to print a photograph on an appropriate paper and obtain a very similar quality to that of traditional argentic prints.

This recent technology has brought about a major change for the amateur photographer. This is also true in the area of small office-home office. It is now possible to edit a document from a company with sufficient quality in terms of the colour of the logo and accuracy of reproduction of the graphics.

This great diversity in quality and fields of application is increasingly forcing paper makers to check the quality of their papers. However, the quality control process used during manufacturing and aimed at determining print quality is not always applicable and reproducible. It is usually based on one or more visual evaluations that cannot easily be transposed from one site to another or even from one operator to another.

These difficulties have led the C.T.P. to develop a complete system for evaluating the quality of ink jet printing, thanks to the skill and experience it has acquired covering printing, measurements and correlations with visual assessment.

Means used

After printing a test form (Figure 1), the print quality is analysed objectively by image analysis. The results of this analysis are automatically correlated with the subjectively assessed print quality. All the ink jet print quality criteria are weighted. These include:

- Optical density
- Gradation curves
- Colorimetry
- Contrast
- Bleeding
- Line sharpness
- Dot shapes
- Text sharpness
- Unevenness
- Print through
- Vignettes

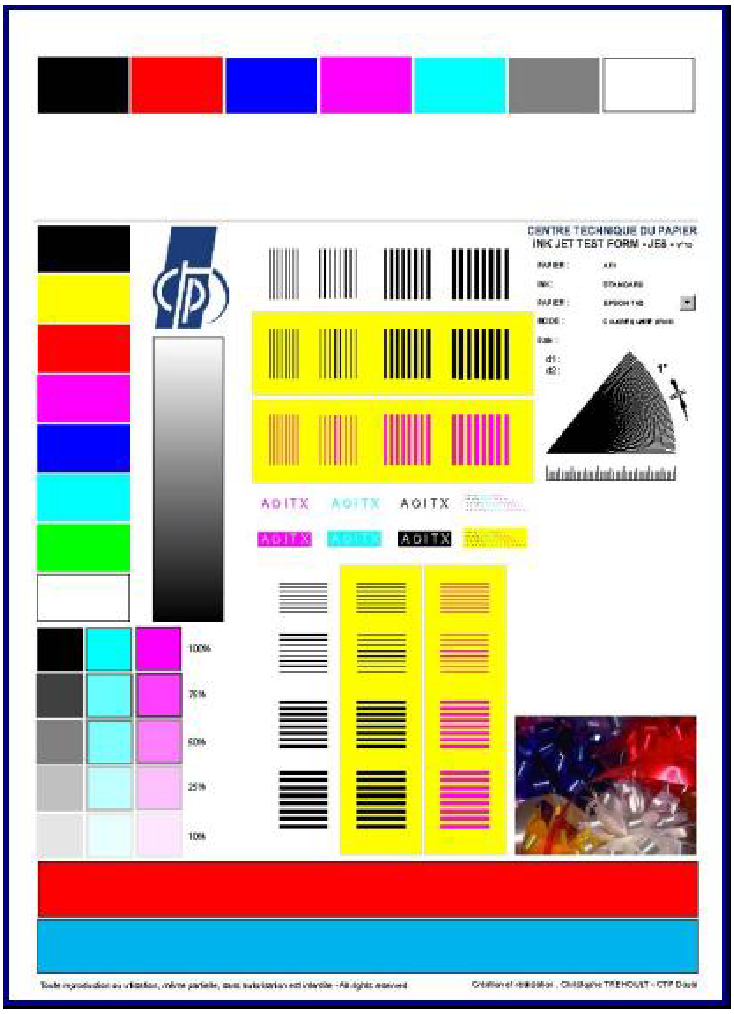

Figure 1 : Test form developed for ink-jet prints

The test form (Figure 1) developed by the C.T.P. includes all the various points required for characterising the defects inherent in ink jet printing, regardless of the paper used.

A set of office and photo printers is selected, taking into account the different characteristics of ink jet printers. By knowing each specific feature of this set, it is possible to examine all the defects encountered in ink jet printing. The set includes machines that use both piezoelectric and thermal technologies, pigment-based and dye-based inks, droplets of various sizes and four or six colour hues.

Once the form has been printed in accordance with a strict procedure, the printed sheet is scanned using various parameters and the resultant images are processed by the image analysis system in accordance with specifically adapted procedures.

A program has been developed to provide maximum sensitivity and speed, while at the same time maintaining a very good correlation with the subjective visual rankings assigned by a panel of experts.

The various indices corresponding to the 11 criteria mentioned above are then weighted to obtain an overall print quality index. Like all the marks assigned to the various criteria, this index complies with a defined scale, that is regularly used to rank print quality, namely 0 = very good and 5 = very poor. 2 is the limit of acceptability.

Results and analyses

- Visual evaluations

The visual evaluations are carried out by printability experts. Initially, a batch of printed samples is selected so as to cover a wide range of defect intensities for each quality criterion. The selected prints are classified and ranked from 0 to 5 by the experts. A subjective quality mark is assigned for each of the 11 criteria. This set of samples acts as the reference and constitutes the visual evaluation scales. It takes long experience and in-depth knowledge of printing to determine such visual scales, and this is not easy to transpose. Any new printed sample is then compared with the reference samples and positioned on the visual evaluation scales.

- Objective and subjective measurements

Two types of measurement may be distinguished

(I) So-called objective measurements, which correspond to optical density, colorimetry, contrast, gradation curves and the topography of raster dots.

(II) So-called subjective measurements, such as bleeding, line sharpness, print through, unevenness, text sharpness and the quality of reproduction of a shade gradient.

These measurements are all done by image analysis. The print is scanned and each criterion is analysed. The greatest difficulty in processing the prints automatically is in obtaining a good correlation between the subjective human evaluation and the artificial vision. To do this, it was necessary to develop a specific methodology in the image analysis processing of each print quality criterion. The processing developed for the subjective measurements gave an excellent correlation between the measurements carried out thanks to the system and the visual evaluations.

- Measurement of bleeding

Bleeding is a phenomenon specific to ink jet printing. If it is too pronounced, it can badly harm the quality of the final print. It appears when two hues are superimposed. This defect is visible in the form of the print running at the interface between the two areas.

The graphic image used (Figure 2) consists of four groups of eight lines of varying thickness. This image is used with black on yellow and magenta on yellow, so that defects can be seen more easily by the human eye. It is represented vertically and horizontally so that it is possible to explore the possible differences that may be found between paper manufacturing direction and print direction.

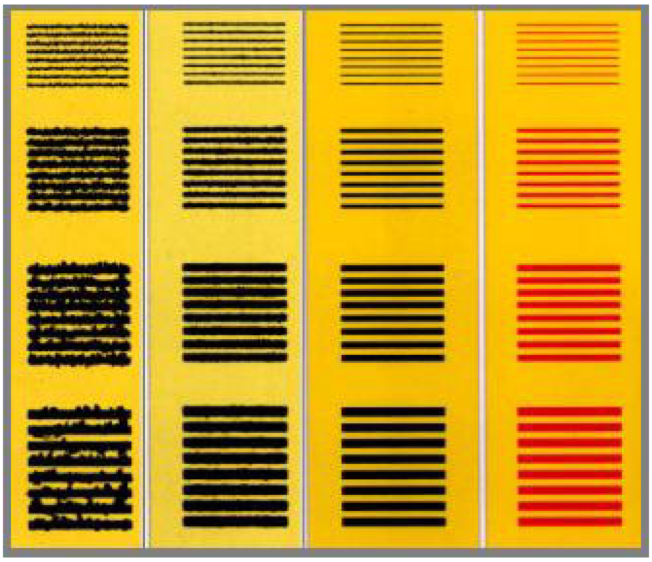

Figure 2:Bleeding patterns on different samples

The human eye detects essentially smudges, but it may also be sensitive to a certain thickening of the original shape. These two aspects are taken into consideration in the processing carried out by the system by carefully weighting the results of each measurement made on the four different line thicknesses.

The correlation (Figure 3) between visual evaluation and the measurement made by the system is very good. The dynamic range of the measurements is maximum for values above 1.5. In the case of values below 1.5, the dynamic range is not so good but the sensitivity of the sensor was reduced deliberately to avoid slowing down the processing speed. As the human eye has difficulty in detecting differences below 1.5, this poses no problem.

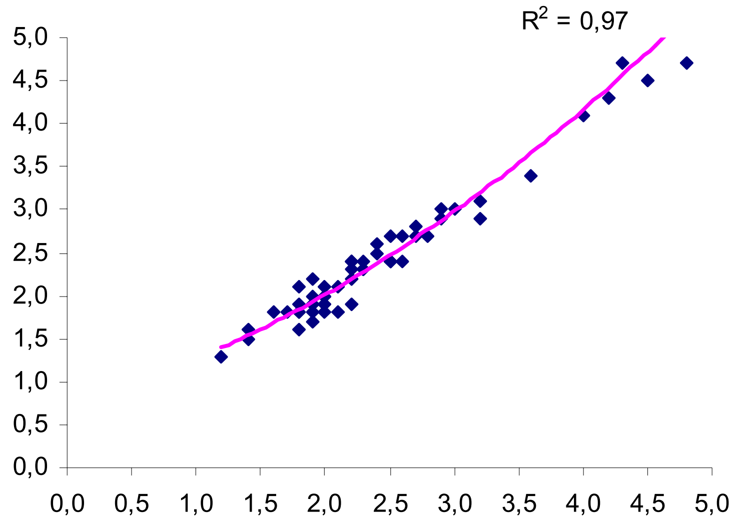

Figure 3: correlation between the two methods: visual and automatic Measurement of bleeding

- Measurement of line sharpness

This is a similar measurement to bleeding, although the two phenomena are not necessarily linked. Bleeding corresponds to the quality of superimposition of two inks, whereas ink spreading relates to the quality of pure ink deposition on the media. Ink spreading varies in accordance with the media but also with the type of ink, printer and ink load. In absolute terms, the aim is to obtain a dot of ink that adheres to the media, dries rapidly and spreads as little as possible to produce a well defined contour with a high densitometric definition. Juxtaposition of the ink dots must produce lines with clean contours, without distorting the shape itself. To do this it is necessary to check the spreading; if it is too small, it will make the juxtaposition of the dots show up too clearly, and if it is too great it is likely to deform the objects.

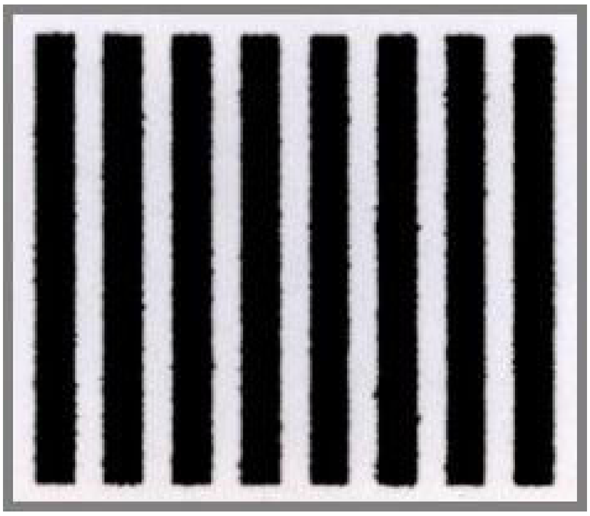

Figure 4 : Pattern of line sharpness

The graphic image selected is the same as that for bleeding but only black is used (Figure 4). The thickening of the shape and irregularity of the contours are the two things that can be detected by the human eye and can be included in an image analysis system.

By weighting each of the measurements, it is possible to obtain a good correlation between the two methods (Figure 5). The dynamic range of the measurements is good over the entire range of samples.

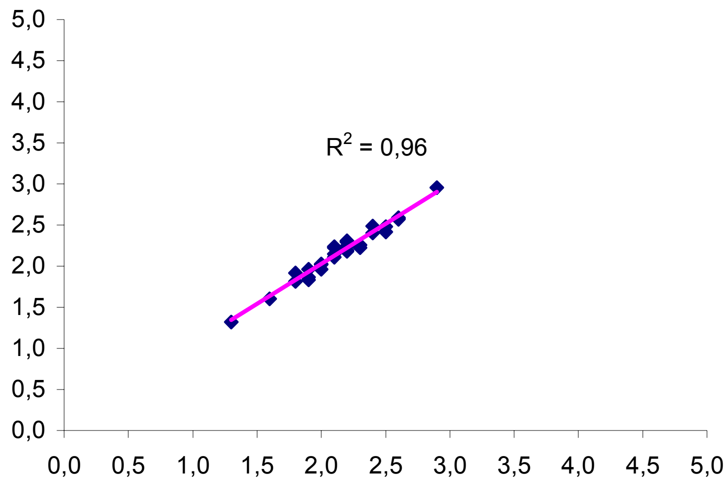

Figure 5 : correlation between the two methods, visual and automatic.Measurement of line sharpness

- Measurement of text sharpness

This is a complementary measurement to that of ink spreading. In addition, it includes characters of chosen shape to explore the various possibilities of shape and orientation. The image (Figure 6) contains 5 letters, AOITX, in Arial 10 font printed in normal mode and in reverse mode. These two ways of using the characters reveal the differences that exist between the samples and thus make it easier to make visual judgments and draw up scales. This image is used in black, cyan and magenta, making it possible to cover a wide spectrum of uses.

Figure 6 : Pattern of text sharpness

The correlation (Figure 7) between the visual evaluation and the sensor is very good, with the dynamic range of the measurements being uniform throughout.

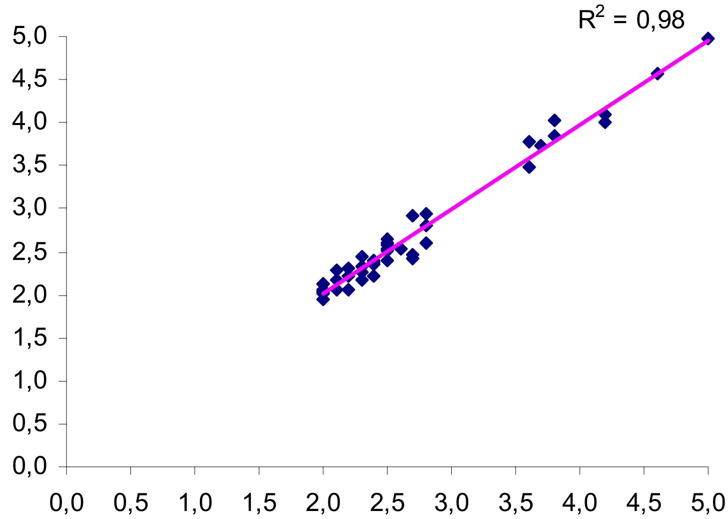

Figure 7: correlation between the two methods, visual and automatic Measurement of text sharpness

- Measurement of print through

The phenomenon of print through is not limited to ink jet printing. It occurs in other forms of printing as well. The level of print through varies according to the ink load, obviously, but also according to the type of ink and medium used. For several reasons it is difficult to assess print through visually. The first is because the operator must measure a signal that is weak in relation to that of the environment, which may be of the same intensity. The second is the lack of consistency in this phenomenon, which is sometimes disturbed by pinholing or strike through. The measurement of print through via image analysis takes these difficulties into account. It is done on the reverse of the print using several ink loads and different colours. As all the ranges are measured against and compared to the paper background, an overall print through index is calculated in perfect agreement with the visual assessment of this phenomenon. The correlation presented in Figure 8 has a very good dynamic range and good accuracy.

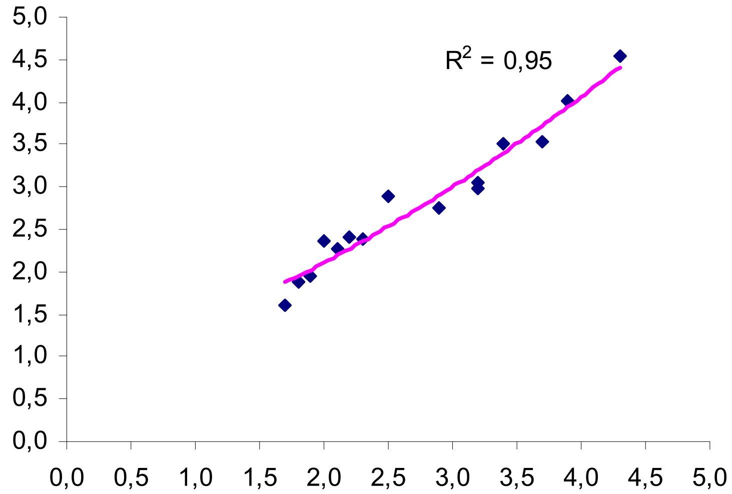

Figure 8: Correlation between the two methods, visual and automatic Measurement of print through

- Measurement of unevenness

This aspect of printing defects is often the most difficult to set parameters for using artificial vision. Unevenness is revealed through the juxtaposition of printed areas of varying density. These areas may be of different shape and size and the variations in density may be more or less pronounced. This defect is not specific to ink jet printing.

Unevenness defects may appear regardless of the colour used or of the intensity of the range observed. The measurements are made over a wide blue area and a wide red area, thus exploring the entire print width of the printer and a wide strip of paper (Figure 9).

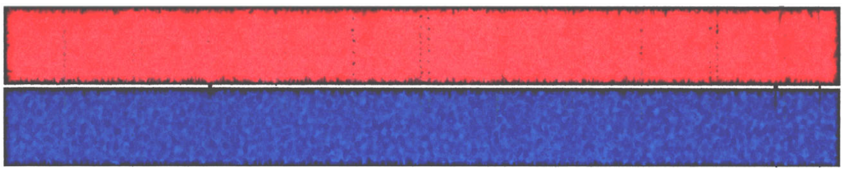

Figure 9 :Graphical image for uneveness

The measurements carried out with the system are not dependent on the general intensity of the print nor on the shape, size and intensity of the defects. This makes the processing very sensitive and gives a good correlation, regardless of the quality of the print (Figure 10). As measurements of this phenomenon via image analysis too often produce a blind area below a value of 2.5, efforts were made in developing the algorithm to avoid this problem.

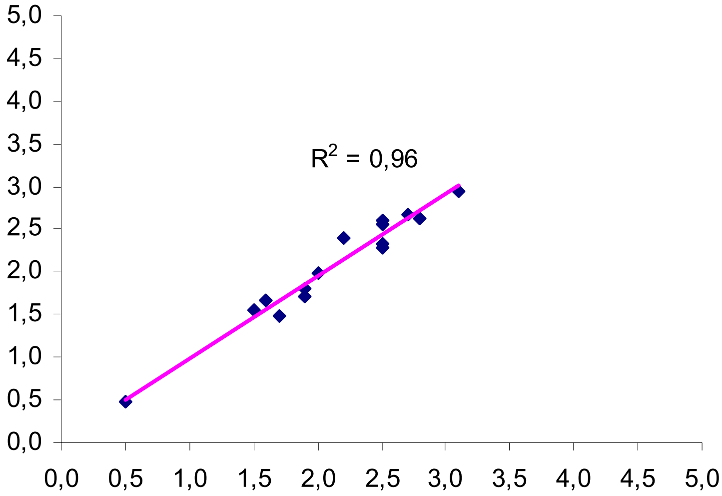

Figure 10 : Correlation between the two methods, visual and automatic Measurements of print unevenness

- Measurements of colorimetry and drift

This part involves drawing up Gamut curves, corresponding to the definition of a spectrum of possible colour reproduction for a printer-media pair. These measurements can be made with a spectrocolorimeter or a scanner. They provide information on the optical density and gradation curves. The aim of the gamut measurement is not considered in this system as an absolute color coordinates definition but rather to control and to get an information of the possibility of the reproduction of color spectrum for a printer-media couple. In addition to make the measure easier, C.T.P. has chosen to measure gamut spectrum trough a scanner using I.C.C. profile technology.

- Measurement of contrast

This measurement is of less importance than the others as information on optical density, ink spreading and quality of shading is theoretically enough to define a value similar to that of contrast. However, as contrast measurement is a standard in the printing world, it is done here, and forms part of the printability criteria.

- Measurement of dot shape

This does not really involve measuring the shape of a dot of ink but of a small cluster of ink dots. An optical system with a greater magnification factor, is in the case of raster dots measurement necessary. As noticed in other ink-jet studies, the printing quality sensed by an user is never in relation with the raster dots measurement.

- Representation of results

In view of the large number of criteria required for evaluating print quality, it is important to represent these 11 results in the appropriate form, which is quick to interpret. It was natural to opt for a "radar" type graph, which provides several axes, while the links between each measurement along the 11 axes produce a spectrum with an area that varies in size and balance (Figure 11).

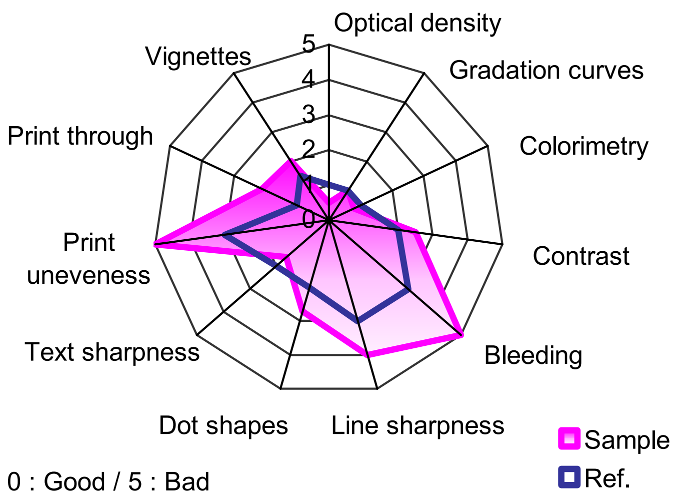

Figure 11 : Radar representation of quality according to the various criteria

Once this spectrum has been established, it is possible to compare it with a general reference spectrum in order to determine which aspect of the media concerned needs attention.

- Weighting of results

By collecting information from the various players in the fields of printing and paper-making, it was possible to determine the weighting factors αi to be applied to the various printability criteria.

These factors can then be applied to the assessment marks ni of the 11 printability criteria selected and to a final overall print quality index calculated in the following way:

$$\text{Overall index} = \frac{1}{A} \sum_{i}^{1 \to 11} \alpha i.ni$$

αi , weighting factor for criterion i

ni , mark assigned by the system to criterion i

A , constant

Allowing for the importance of each print quality criterion, the overall index is in phase with the visual sensation that an observer might have when looking at a complex image (Figure 13).

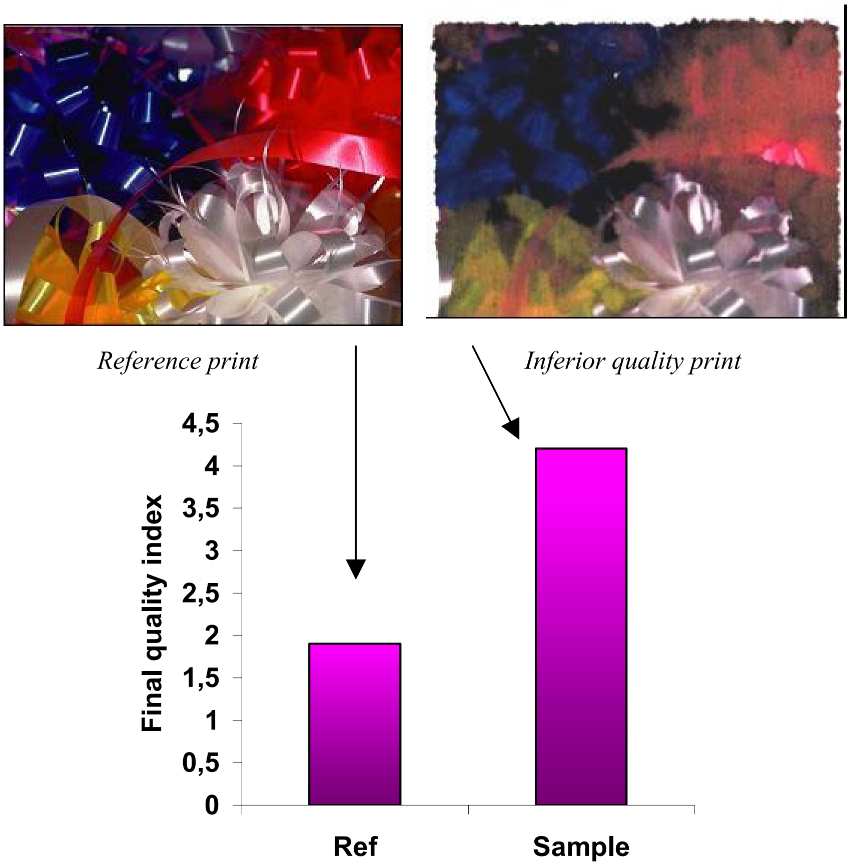

Figure 12 : Overall print quality for a good quality reference and inferior quality print

Conclusions

A single reliable and reproducible new method is proposed for evaluating print quality on ink jet printers. This method, which replaces human evaluations that are often called into question, is based on the expertise and knowledge gained by the C.T.P. in fields connected with paper, coating, printability, data processing and image analysis. It is based on:

- A specific ink jet printer test form that reproduces all the defects found in this type of printing,
- A set of ink jet machines that are commonly found on the market and are representative of the different characteristics of the equipment is selected.
- An image analysis system, with algorithms suited to measuring each of the print quality criteria,
- Knowledge of the levels of quality of printers available on the market.

A print quality index is given to the users in a full automated way; this assessment is in perfect correlation with visual perception.

Bibliography

"Reliability Issues for Color Measurement in Quality Control Applications"
John C. Briggs, David J. Forrest and Ming-Kai Tse
(IS&T NIP14: International Conference on Digital Printing Technologies, Oct 18-23, 1998, Toronto, Ontario, Canada)

"Print Quality Analysis as a QC Tool for Manufacturing Inkjet Print Heads"
David J. Forrest, John C. Briggs, Ming-Kai Tse, and Steven H. Barss
(IS&T NIP14: International Conference on Digital Printing Technologies, Oct 18-23, 1998, Toronto, Ontario, Canada)

"Automated Print Quality Analysis in Inkjet Printing: Case Study Using Commercially Available Media"
Ming-Kai Tse and Alice H. Klein
(IS&T NIP14: International Conference on Digital Printing Technologies, Oct 18-23, 1998, Toronto, Ontario, Canada)

"Automated Test Equipment for the Development of Media for Digital Printing"
Ming-Kai Tse and Alice Klein
(ICPS 98: International Congress on Imaging Science, Sep 7-11, 1998, Antwerp, Belgium)

"Automated Print Quality Analysis for Digital Printing Technologies"
Ming-Kai Tse, David J. Forrest, and John C. Briggs
(PPIC/JH ’98: The Society of Electrophotography of Japan, Pan-Pacific Imaging Conference/Japan Hardcopy ’98, July 15-17, 1998, Tokyo, Japan)

"A Report on a Subjective Print Quality Survey Conducted at NIP16"
Gretchen Gast and Ming-Kai Tse
(IS&T NIP17: International Conference on Digital Printing Technologies, Sept. 30 - Oct. 5, 2001, Ft. Lauderdale, Florida)

“Automated image quality tests for printer evaluation”
Application notes version 2.04
KDY Inc. Publications 1998

“Automated image quality tests for the evaluation of receiving media”
Application notes version 3.0
KDY Inc. Publications 2000

« Benchmark test on color ink ket printers using KDY system »
PC Magazine November 4th, 1997

“Influence of mottle on color reproduction”
Christine Canet
IARIGAI 28th Research conference

“A method for measuring ink-jet wicking using a document scanner and a personal computer”
Roy Rosenberg
TAPPI Journal 81 vol 3, March 1998

“Image analysis of ink-jet quality for multi use office paper”
G.E. Kowalczyk & R.M. Trksak
TAPPI Journal 81 vol 10, October 1998

“Optical homogeneity of prints”
Per-Ake Johansson
Doctoral thesis, Kungl Tekniska Högskolan – STFI

“Band-pass image analysis as a tool for print mottle evaluation”
P-Å. Johansson
Proceedings of 2nd European Research Symposium on Image Analysis for Pulp and Paper Production, Darmstadt, 2-3 September 1993.

Evaluation of calender blackening, mottling and missing dots by a PC based image analyser
H. Praast
Proceedings of 3rd European Research Symposium on Image Analysis for Pulp and Paper Research and Production, STFI, Stockholm, 12-13 June 1995.