Objective Print Quality Measurements Using a Scanner and a Digital Camera

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Abstract

Print quality is still almost exclusively evaluated visually, due to tradition as well as the unavailability of certified measuring devices. This article shows that by use of a low- and a high-resolution measuring device (flatbed scanner, digital camera) many print quality parameters can be measured in an objective, reproducible and fast way. The measurements are carefully designed to atch the average visual impression but are independent of the subjectivity of a visual evaluation and allow objective comparisons of different printing machines.

The paper focuses on the parameters that can be measured on flat field prints like process color density, density variations within sheet and its special attributes like streaks, banding, mottle, granularity, background and satellites. These parameters are measured using an analysis system based on a scanner and a digital video camera.

Finally the presented analysis system is used for an objective comparison of the flat field printing performance of different digital printing machines.

Introduction

To evaluate the performance of one or more digital printing machines and retain objective and comparable results, it is necessary to utilize measurement methods that are based on reliable measurement devices. The traditional visual quality assessment is too much dependent on the observers, their different interpretation of certain defects and the environment conditions.

Flatbed scanners have been employed for density variation measurements since several years[1,4] because of their inexpensiveness and ease of use. They have already been proven reliable for that application.[2] To increase the analysis performance for high-resolution measurements a digital video camera with a microscopic lens system is employed. While a high performance flatbed scanner is able to measure up to a resolution 10µm per pixel, the camera system we used delivers sharp images at 1.5µm per pixel.

With that range of different resolutions it is possible to measure all flat field defects ranging from several cm to a few µm. E.g. mottle and streaks show fairly low frequency ranges and can therefore be measured on a low-resolution image. Granularity and banding need a higher resolution, while flat field artifacts like background and satellites can only be measured on an extremely high-resolution image. Samples of the defects are shown in figure 1, 2 and 3.

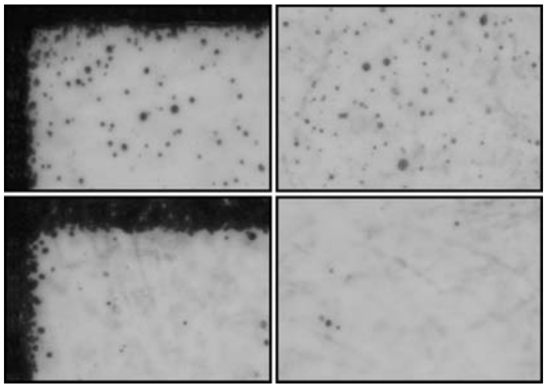

Figure 1. Satellites(left) and Background (right), much and little.

The Measurements

The measurements shown above can be divided into 2 groups:

1. Mottle, Granularity, Streaks, Banding
2. Background, Satellites

The parameters of group 1 can be considered as density variations in halftone flat fields, while the parameters of group 2 describe toner laydown in unprinted areas.

Since group 1 parameters characterize density variations it is appropriate to use the scanner image for density measurements. For the single process colors cyan, magenta, yellow and black this can be done with high accuracy, as described in the next section.

Parameters of group 2 are defined through the print density created by toner particles in unprinted areas. This density must not exceed 0.013D.[5] Since such a low density is barely measurable with a densitometer or scanner, a particle detection and counting algorithm that returns exact particle sizes on high resolution images is required.

Designing the Measurements to match the Visual Impression

Calibration of a Scanner to Print Density

It has already been proven that for measurement purposes a scanner calibration is necessary and that a single process color calibration returns more reliable results than a full color calibration[3]. Because we want to measure density differences in single color flat fields, it is reasonable to calibrate the scanner output to process color density. The density calibration is done by using a scanner-response to density conversion table.

The average absolute error of the scanner density measurement is 0.01D. The maximum errors found for more than 100 measurements in all four colors are 0.03D. The accuracy tests were done on an Epson Expression 1640 Scanner using prints from two different machines on glossy coated paper.

To ensure the calibration stability over time, certain measurements have to be repeated every three months on a defined set of print samples. Through the last year no value drift was seen.

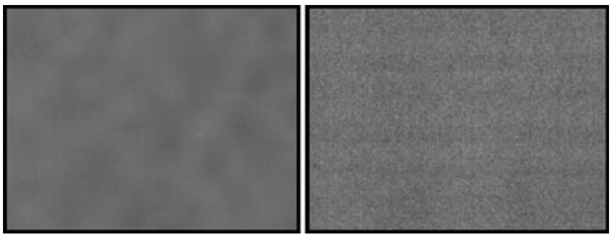

Figure 2. Mottle (left) and Granularity (right)

Calibration of Particle Sizes

The evaluation of background and satellites is based on small particles and their size. These particles are counted and measured exactly, since more and larger sized particles result in a much higher visibility and a higher background density. Our measurements concentrate on particle diameters from 5µm to 40µm. Particles with less than 5µm almost do not contribute to the visible density while particles with more than 40µm are visible as single clusters and do not add to a density sensation.

On a microscopic digital camera image electro-photographic toner particles have no sharp edges and the particle size is very much dependent of the detection algorithm tuning. Therefore the exact sizes of defined particles were determined with a measurement microscope. The camera-detected sizes were calibrated to match these values. Of course the light condition and the camera settings have to be carefully defined and constant to guarantee the long-term measurement stability. As for the density measurements, certain samples should be checked every three months to ensure this.

Using our image analysis system (KDY/Image Expert) the average error of the cluster diameter is 1.3µm with a maximum of 4µm for 40 evaluated clusters in the range of 5µm to 40µm. In this range 98% of all existent particles are detected and only 3% of the detected particles up to a size of 10µm, are mismeasurements due to paper structure or dust.

Matching of Measurement and Visual Impression

After being sure that the measurement is correct and stable over time, the next step is to design the evaluation parameters in order to match the visual impressions of the print regarding the parameters.

Therefore psychophysical studies were designed, that research the visual objectionability of different levels of severity for the parameters stated above. For some of the parameters the study design and the results can be found in the literature.[5,6] Using the results of this visual evaluation it is possible to design algorithms that approximate the average visual scores of the tested persons.

In this paper it is not possible to describe all measurement algorithms, only for streak measurement a little more detail is given in the next section. For the other parameters just note that banding is based on calibrated density variation profiles as shown in figure 3. Mottle and granularity measurements use a 2D Fourier transform to filter the spectral energy for the different frequency ranges. Background and satellites are based on the calibrated cluster sizes. Possible algorithms for streak[4] and for background[5] measurement can as well be found in the literature.

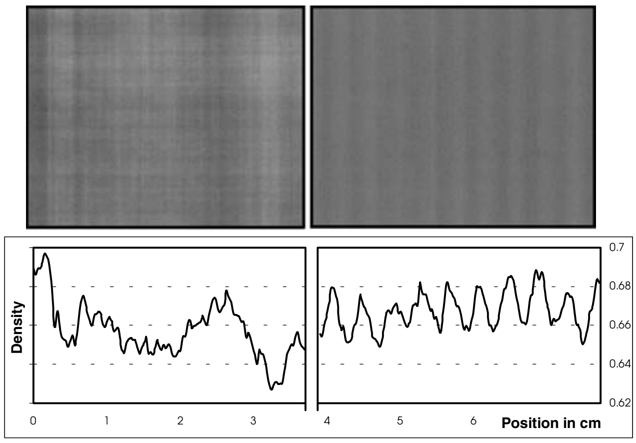

Figure 3. Streaks (left) and Banding (right) with density profiles.

Designing an Algorithm for Streak Measurement

As a sample for the procedure described above, only the streak measurement is described in more detail. A psychophysical study was carried out to evaluate the visual objectionability of streaks in flat field images. In the study 100 prints were used, showing flat fields in single process colors CMYK with different levels of streakiness. These were rated by 12 observers with a score between 1='excellent' and 6='totally unacceptable'. The scoring was done for each color separately and it was possible to compare prints.

After that an algorithm was designed that returns a single number as a score for the streakiness of a print. All 100 prints were tested by this algorithm and the correlation between visual and algorithm score was analyzed, with a special attention on outliers. In 5 iterations the algorithm was changed and tuned to represent special features that were found on these outliers. The final algorithm shows good correlation between visual and algorithm scoring, shown in figure 4 for black flat fields. The average error for all 100 prints is 0.1.

The streak algorithm operates on a density profile as shown in figure 3. The profile is generated by a calibrated scanner and is an average over a 5cm wide image strip. It shows the density variations on the print in one direction. Dependent on this profile the algorithm score is calculated from the absolute density changes, the gradients of the density changes and the width of the single streaks.

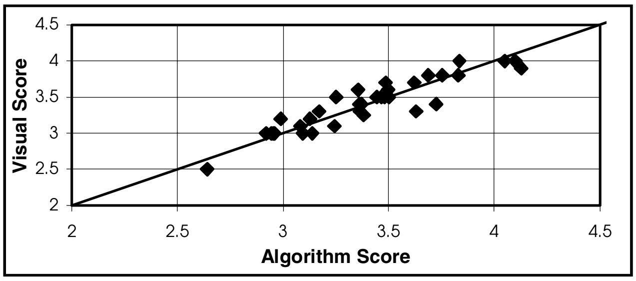

Figure 4. Correlation between visual and algorithm score for streaks on black flat fields.

Using Objective Measurements to Compare Different Digital Printing Machines

Having algorithms that provide objective print quality measures allows us to compare different digital printing machines and technologies. In Figure 5 the described parameters are used to compare toner-based machines of different vendors to good DI offset print quality.

Every column is based on data of two up to five machines from the same vendor. All values are displayed on a scale of 1='excellent' to 6='totally unacceptable'.

Discussion of the Comparison

Looking at these results we can find some differences in the image quality for toner and DI-offset machines, as well as for toner machines from different vendors.

The streak performance is good for the offset machines. For the toner machines the streaks range from 2.7 to 3.7, which means that the streaks are in most cases clearly visible but not severe. Single machines show big differences in- and cross-track direction, in-track streaks are aligned in paper transport direction, cross-track streaks are orthogonal to these. While most of the machines have more streaks in cross-track direction, machine A shows offset performance for cross-track but has problems with in-track streaks.

Mottle is the only parameter where all machines perform well, granularity is a little worse for the toner–based machines, with machine B showing severe problems. Background and satellites is generally higher for toner based machines, only machine D performs equally well as offset and machine A clearly outperforms the others.

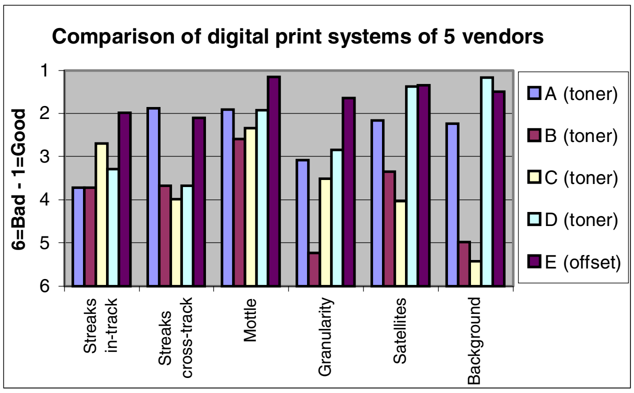

Figure 5. Objective comparison of different digital print systems.

Conclusion

It was shown that by using a flatbed scanner and a digital camera it is possible to replace subjective visual print-quality evaluation by objective, long time stable measurements. This allows an objective comparison of different printing machines and technologies.

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Biography

Birger Streckel studied Computer Science in Kiel and received his diploma in the field of image processing / computer vision in late 1999. Since then he works at NexPress GmbH in the Image Quality department. His current research interest is automated print quality analysis of digital prints.