Scanning Image System for Print Quality Measurements

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Abstract

Printronix, Inc. uses scanner-based image systems to perform print quality measurements for line-matrix printers. The size of the image samples and image definitions requirement make commercial scanners convenient to use. The scanner-based image quality measurement system has been utilized to increase repeatability and accuracy. Printronix has developed software package, based upon MATLAB, which permits the use of standardized algorithms to interpret the data. The PC based analysis tool can process data efficiently and yield more accurate results. Additionally, the new method can provide in-depth information on individual attributes that contribute to the overall visual perception of image quality. This paper presents the measurement and analysis methods of determining the quality of prints generated by line matrix printers. Several key image quality aspects such as dot density, dot size, dot uniformity, dot positioning, and ink smearing measurement, are discussed in the paper.

Introduction

Line-matrix printer applications require the use of unique image analysis tools to interpret the print quality. The quantification of print quality associated with impact printing is correlated to dot density, dot size, dot shape, dot position and dot uniformity, page printing uniformity, and print contrast. By using modern high-resolution scanners, the image quality can be ascertained in a repeatable and reliable manner. This new scanner-based image system can also support the evaluations of large volumes of data, provide image characterization and customized analysis for specific applications.

Image Quality Measurement

The measurement described in this paper have been carried out using a high-resolution flatbed scanner-based image system adapted to collect print quality data of sample images. Print samples are generated using a PRINTRONIX P5000 line matrix printer, which has tip size of 0.016".

Image Quantification System

Scanner

A commercial 1600-dpi flatbed scanner is chosen as the input device for the image quality measurement. Image quality attributes collected by the system for verification require a resolution greater than 600 dpi, and this can be readily accommodated by using this scanner.

Scanner Calibration

In order to maintain the accuracy of the analysis, a calibration run is performed at the start of each scan session, using a NIST traceable reflectance standard. The dimensional accuracy of the scanner is done by scanning a reference test pattern such as the ones used for calibrating photocopiers. A set of ANSI X3.182-1990 barcode standards is used for reflectance and dimensional accuracy calibrations.

Measurement Method

Images are read and stored in gray level (photographic mode) format using the appropriate resolution. In most cases, we are scanning with 600dpi resolution for density interpretation applications, and higher resolutions are used for dimensional measurements. The smallest features being measured determine the required minimum resolution. In the case of measuring the impact prints, the smallest features needed are about 16 mils in size. Variations in print quality are resolved within this resolution. Features as small as 1/100 dot size can be analyzed effectively. This resolution allows to the analysis of the dot. See Figure 1.

Analysis Method

The data from the image is analyzed through a multiple step process:

- Filtering
- Digitization
- Segmentation
- Component Processing

Filtering and Digitization

Filtering is done using a fast reset moving average filter.[2] The image data is smoothed out for the first digitization pass, and the fast reset takes unwanted tails out of the digitized image, see Figure 2. The filtered data is digitized with a simple threshold, and the binary image is used in the subsequent digitization processes. In the subsequent passes, data is digitized based on a maximum entropy method.[2] The image is divided into smaller regions. A histogram of each region is taken on the grayscale data where the binary values from the last pass are black, and another histogram is taken where the binary values from the last pass are white. The sum of the histogram values are taken for both the white and the black regions and the value is stored. This stored value for each pass of each region is compared to other passes during the multiple step digitization process. The threshold is varied for each pass and a binary image is produced for each pass. When the maximum value is found, the threshold for that pass is used for subsequent scans of the same scanning session for the same media.

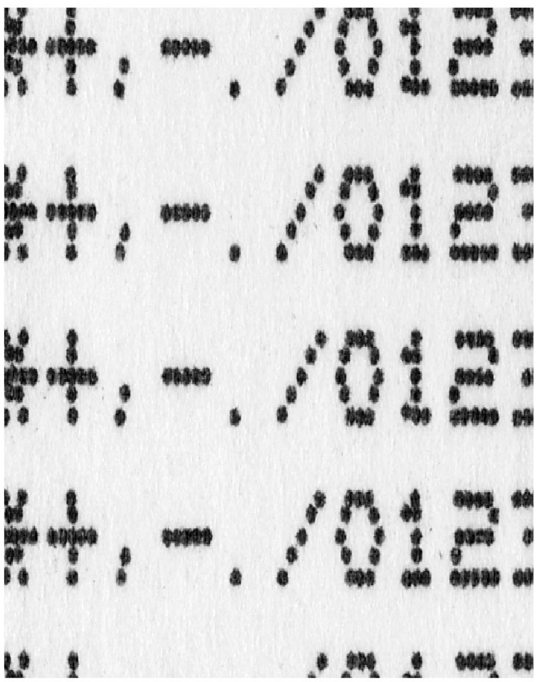

Figure 1. ASCII Print Sample

Segmentation

The entire digitized image data is subdivided by using a simple component-labeling algorithm. A row-by-row algorithm with 4-neighbor connected components is used. This allows subdividing dots on a printed page that are just partially connected. See Figure 3.

Additional processing may be required for those dots that have been merged into a larger mass, note that in Figure 3, that there are multiple dots merged into a single segment. In a typical printing application it is desirable to merge the dots and keep the dots uniform. This gives the user the perception that they are not looking at dots, but rather the intended printed character or object, Figure 4a. On the other hand, it is necessary to separate the dots into separate entities in order to analyze them in a real printing situation. One method that has been incorporated uses the Watershed Transform.[1] This method separates the dots into separate entities, Figure 4b. The first step uses the binary image and a distance transformation is performed, Figure 5.[3] The unfilled regions found from the watershed transformation are zeroed along with the regions where the binary image is also zero. This gives the result shown in Figure 4b.

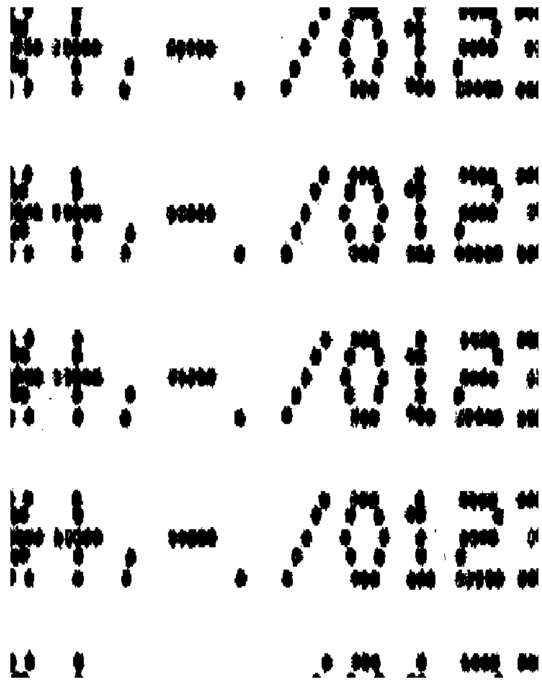

Figure 2. Digitized Sample

Figure 3. Simply Segmented Image

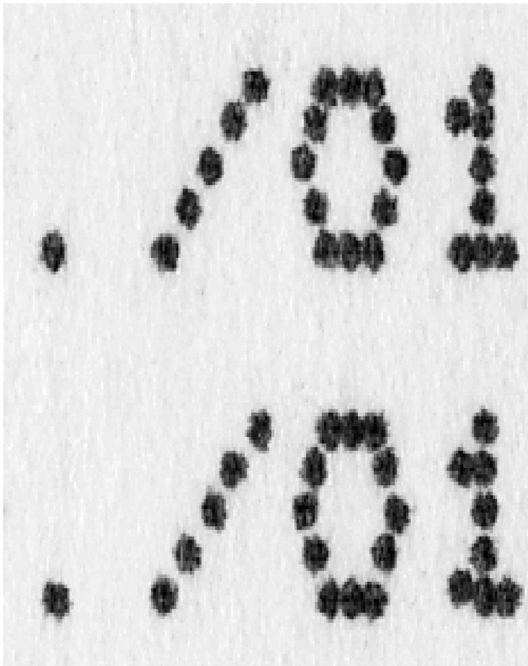

Figure 4a. Print Sample with Merged/Unmerged Dots

Figure 4b. Segmented Image

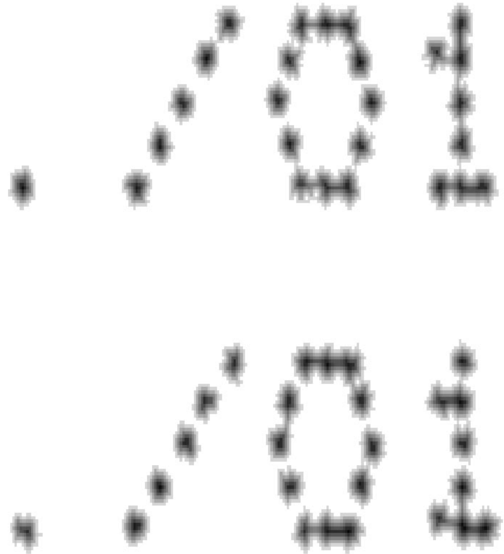

Figure 5. Distance Transformed Image

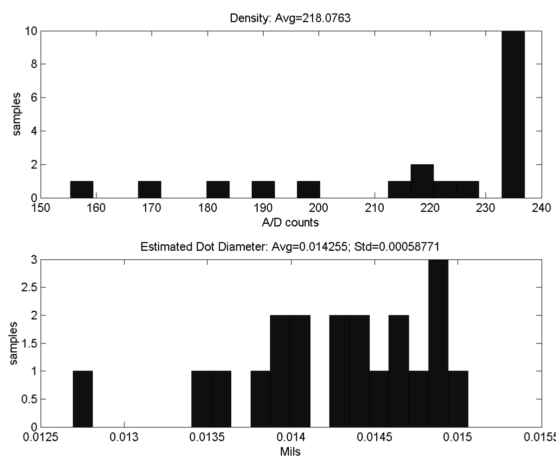

Figure 6. Dot Analysis Results

The area, center of mass and the relative density are analyzed. Figure 6 shows a histogram of the dots analyzed from Figures 4a and b.

Component Processing

For each component, every segmented pixel is processed along with its associated grayscale value to find the weighted center of mass and orientation.[3] Then, the component can be analyzed for its size, shape and position, and can be related to the same characteristics of the neighbors.

Applications

Ink Smearing

Ink smearing occurs in the region in between adjacent wet dots. A dual threshold method is used to find the lightest gray regions and the darkest regions within a component. The same basic segmentation algorithms are used, but twice. This will define the amount of "smearing" for each dot component. In this way, smearing can be determined regardless of the absolute shape of the components being analyzed. Degree of smearing can be defined by the ratio of the area found with a dark and a light threshold. The ratio provides a mean to gauge the extent of the smearing.

Dot Registration

Maximum horizontal and vertical displacement of dots within a character can be measured. The dot displacement is defined as the normal distance from a straight reference line to a dot center.

Black Plot Density

Black Plot density is one of the standard measurement methods that has been used for gauging the impact printer ribbon life tests. See Figure 7. The scanner-based image system results are based on the absolute references, which provide more information and can collect more data points than the traditional densitometer method could handle.

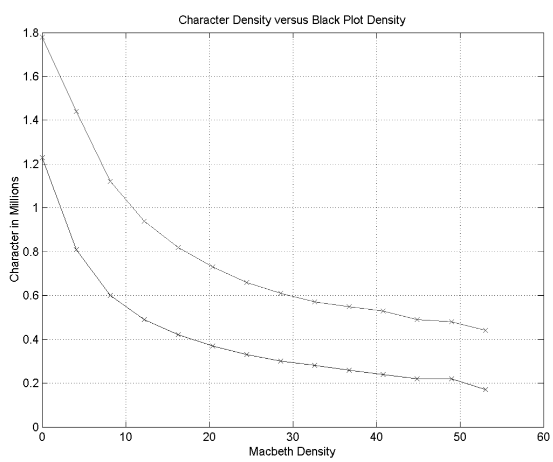

Figure 7.Ribbon life based on Character Density and Black Plot Density

A commercial densitometer uses a preset aperture to sweep across the printed black plot images to measure the means of image quality. The aperture on the standard den-sity meters varies from 5 to 10 pixels. It is used to deter-mine the uniformity of a printed black plot image. The actual estimated density is derived from a simple calcula-tion to divide the grayscale data by the number of pixels summed. It is simple to simulate the effect of the densito-meter using the image techniques described in the paper. A simple 2-D averaging filter can simulate a 5 to 10 pixel aperture. The resultant data is then averaged. The other method is a simple average of all the pixels inside the desired analysis region. A character plot and a black plot are per-formed at each data point, and the results are used to deter-mine the quality of the print at each data point, which could be related to the ribbon printing duration, for example.

Character Density

Character density is another important parameter that uses the individual dot analysis to interpret the print quality. See Figure 7.

To subdivide a text-printing sample, which contains many characters, horizontal and vertical projections are taken. These profiles are analyzed using an FFT of the vertical and horizontal projections.[2] The dominant harmonics are used to determine the character pitch and the row size. The page is segmented on a grid determined by these dominant harmonics. Characters are individually processed in this manner. This method works for a variety of fonts as long as they have a standard pitch. Each character is digitized and the darkness is measured using the method outlined above.

For more complex text or graphics, the segmentation algorithms outlined above can be used along with custo-mized clustering algorithms.

Conclusion

The scanner-based image analysis methods are developed for determination of the print quality of the impact printing technology. This new method can be used for applications such as the print quality measurements and ribbon life evaluation. The scanner-based image system performs print quality measurements to match human visual perceptions, and enables increasing throughput of data collection while decreasing the operator intervention. General-purpose algorithms have been implemented and developed by Printronix to simplify the analysis of the print data.

References

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Biography

Jeng-dung Jou received his Ph.D. degree in Chemical Engineering from UCLA. He has been working on ink and ink ribbon development and print quality analysis for line-matrix printer at PRINTRONIX, Inc. Lihu Chiu received his bachelor's degree in Electrical Engineering from Northeastern University. He has been involved in barcode reading and analysis for six years at PRINTRONIX, Inc. Grant Chang received his Ph.D. in Metallurgy from University of Utah and currently is Director of Engineering at PRINTRONIX, Inc.