

Repurposing Device-dependent Screens for Unintended Printers

*Stephen K. Herron
Xerox Corporation
Rochester, New York*

Abstract

Screened images of 1-bit depth are common in the office market and in graphic-arts printing systems. Bitmapped screens are produced at the copier scanner, copy-dot scanners and in the Digital Front End (DFE) as "digital negatives." Raster-once-output-many (ROOM) is an example of a digital negative. Such bilevel images are printer device specific. The bilevel image may be inappropriate for the printer in use and the original image may be unavailable.

While inverse halftone is a common solution for repurposing screened images, it results in lower quality reproduction:

- Inverse halftoning requires further density compensation for the requirements of the new printer.
- Much of the original image information is lost in the depth to frequency conversion and inverse halftoning cannot reclaim the lost image data.
- Rescreening a reverse-halftone image results in loss of high-spatial frequency image data.

The goal of the algorithm described is to increase screen-repurposing performance and maintain high-frequency detail without inverting the 1-bit image to 8-bit.

Introduction

Printing a device-dependent image on another output device without inverting the screen to grayscale is the result of a series of image processing algorithms. None of the individual algorithms is unique. The process described is the result of selection and modification of current image processing methods.

The 1-bit image consists of a halftone dot screen. Each dot in the halftone consists of a cluster of micro-dots. For simplicity, a halftone screen is used as a generic term to include all screening types including diffusion and blue-noise mask screens. An inverse halftone algorithm converts the 1-bit micro-dots to an 8-bit image. The inverted image in this case is referred to as a pixel-map. The pixel-map is used to guide the re-screening process and is not used as an image source. The resolution of the

pixel-map may be the same as the number of halftone dots in the unit, e.g. a laser printer may position 600 micro-dots per inch forming 85 halftone dots per inch at 100 gray levels. The described method produces a pixel-map of the same resolution as the halftone dot screen; however memory limitations and algorithm deficiencies may result in a pixel map of even lower resolution.

Overview

Three conditions must be met in order to successfully repurpose a screened image for reproduction on another printer:

1. Adjust the image density from the density curve appropriate for the original printer to that of the new printer.
2. Scale the printer microdot resolution from the original device resolution to the new device resolution.
3. Change the screen-type or dot-pattern from the original screen to the screen required by the new printer.

Figure 1 shows a high-level flow diagram of the algorithms and their order of execution.

The algorithmic process involves:

1. Generate a TRC that describes the density difference between the old and new printers and use it to map the density requirements of the new printer to the current image halftone data.
2. Perform an inverse halftone of the image.
3. Apply the density-difference TRC to the inversed halftone to produce a pixel-map.
4. Adjust the original screened-image densities to match the new printer. Use a novel merge-pixels algorithm that adds and subtracts dots following the pixel-map.
5. Scale the screened image from the resolution of the original printer to the resolution of the new printer.
6. Rearrange the halftone pattern to a halftone pattern compatible with the new printer using either a template replacement LUT or a FM noise-reduction method.

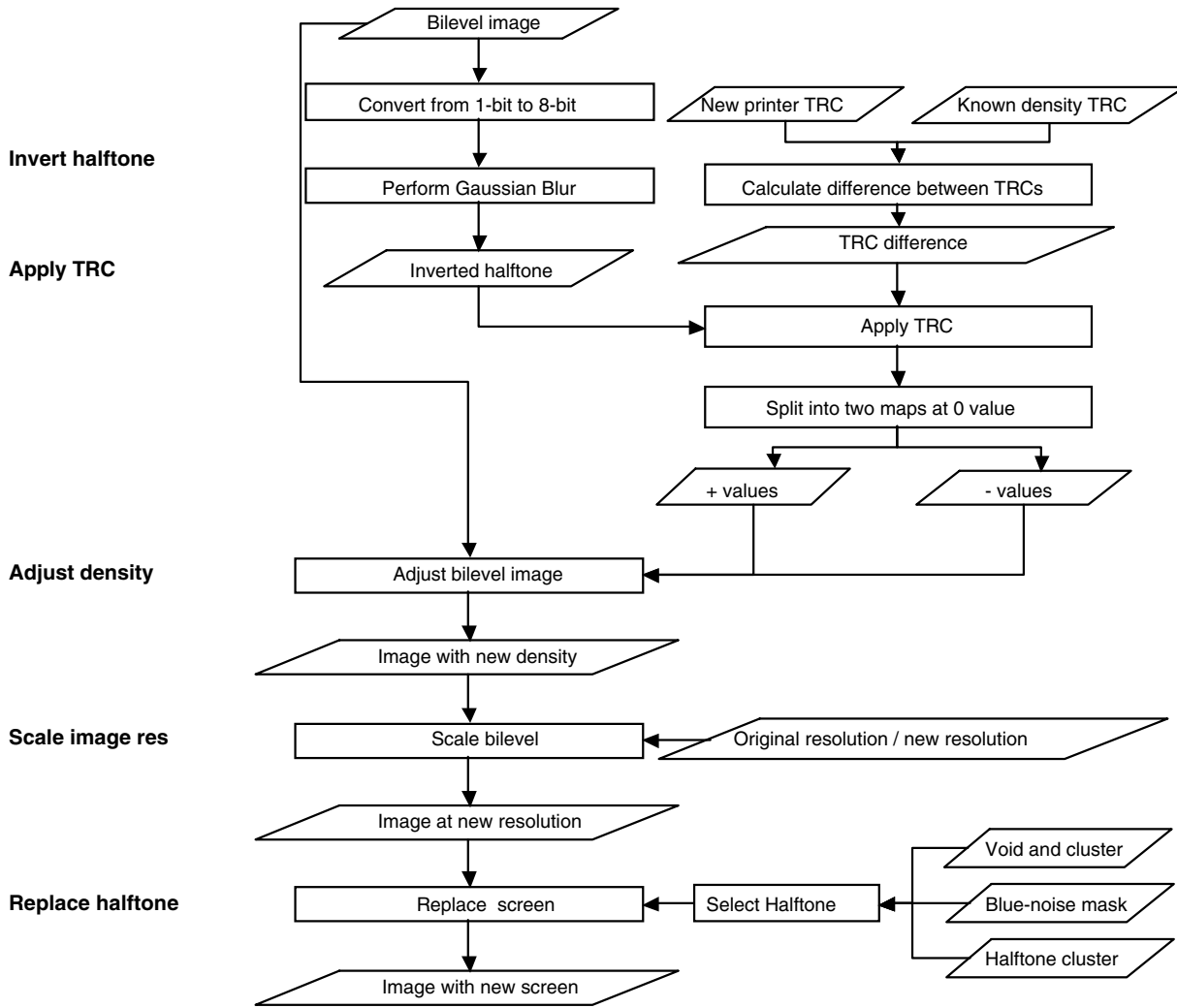


Figure 1. Screened-image repurposing flowchart

Details of the Process

Start with the original bilevel image. The image shown in *Illustration 1* consists of an elliptical halftone screen.

1. Produce a density difference TRC. The TRC is derived from known printer characteristics of the original printer and the new printer. These characteristics include white point, black point and the point of greatest difference from the linear. *Figure 2* illustrates the calculation of the density difference TRC. The charts are not representative of a particular printer.
2. Inverse halftone technologies considered include:
 - Wavelet decomposition
 - MAP estimation
 - Edge-sensitive filtering methods
 - Spatial adaptive low-pass filtering

While any of these technologies may be used, each has its own benefits and problems. For this implementation, a common Gaussian filter was used to perform the inverse halftone.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

where x, y are the image coordinates, σ is a standard deviation.

The Gaussian^{1,2,3} is a gross method of changing pixels at 1-bit depth to 8-bit depth pixels. The Gaussian filter acts on the data that describes the density difference between the two printers. Therefore the density range is small and errors are small.



Illustration 1. Original screened image and an enlargement

The Gaussian produces the pixel map of the image. The inverse halftone is used as a map to add or subtract micro-dots to or from the halftone image. The depth of each pixel determines the number of micro-dots to be added or subtracted.

The resolution of the pixel map is equal to the resolution of the halftone dot screen or the blue-noise mask size. A Gaussian representation of *Illustration 1* is shown in *Illustration 2*.

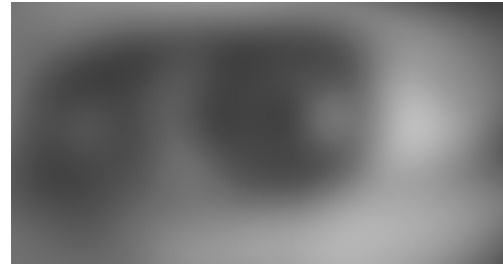


Illustration 2. Inverse Halftone

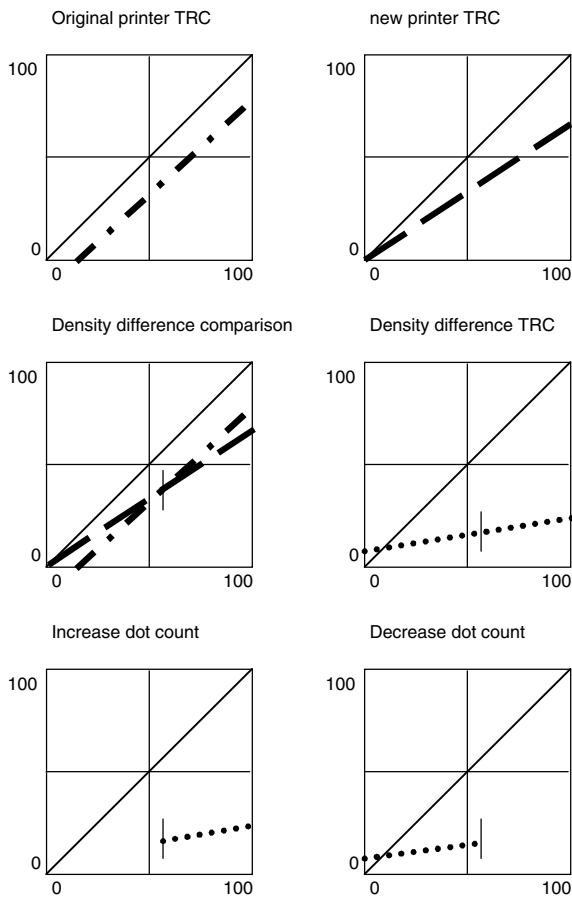


Figure 2. TRC differences

3. The application of the density difference TRC is a simple one-dimensional TRC or LUT replacement procedure. The result of the pixel replacement of *Illustration 2* resembles *Illustration 3*. The typical range of grays is between -12 and 12 gray levels.
4. Two pixel maps are made following the two TRCs diagrammed in *Figure 2*. (Output not shown.)



Illustration 3. Density difference pixel map

5. The next step is to add or subtract micro-dots following the pixel map. The result is simulated in *Illustration 4*.

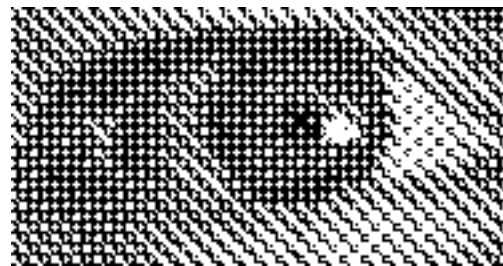


Illustration 4. Result of density difference

Future Work

The algorithm can be improved by processing the page according to its content. Images and text have different characteristics and therefore should either be segmented and processed differently or the inverse-half-tone filter must ignore text and line structures. Scaling and dot-screen replacement of text is inappropriate causing artifacts and warped letter forms.

The algorithm is tested on black-dot printer engines producing grayscale. Extending the algorithm to reproduction of color separations for color digital copiers is the next step.

References

1. S. Cheung and R. Ulichney, *Window-Extent Tradeoffs in Inverse Dithering*, Sixth Color Imaging Conf., IS&T, pp. 245-248, Nov., 1998
2. Ravishankar Rao, Frederick Mintzer, Gerhard Thompson, *Descreening Printer-Ready Images*, IS&T's NIP 14: International Conference on Digital Printing Technologies, Toronto, Ontario, Canada; October 1998; p. 285-289;
3. Z. Xiong et.al. *Wavelet-based Approach to Inverse Halftoning*, Fifth Color Imaging Conf., IS&T, pp. Nov., 1997
4. Michel J. Denber, *Image Quality Improvement by Hierarchical Pattern Matching with Variable Size Templates*, Patent # 5365251, Xerox Corporation, 11/15/94
5. R. Ulichney, *The Void-and-Cluster Method for Generating Dither Arrays*, IS&T/SPIE Symposium of Electronic Imaging Science & Technology, San Jose, CA, vol 1913, pp. 332-343, Feb 1-5, 1993
6. T. Mitsa and K. J. Parker, *Digital Halftoning Technique Using a Blue-noise Mask*, J. Opt. Soc. Am. A, vol 9, pp. 1920-1929, 1992
7. M. Denber, *Image Quality Improvement By Hierarchical Pattern Matching With Variable Size Templates*, Patent 5365251, Xerox Corporation, 11/15/94
8. Thomas I. Yeh et al, *Method And System For Performing Perspective Projection Conversion*, Patent 5742708, Xerox Corporation, 04/21/98
9. Ricardo L. deQueiroz et al, *Method And Apparatus For Wavelet-Based Universal Halftone Image Unscreening*, Patent 5799112, Xerox Corporation, 08/25/98

Biography

Stephen Herron is manager of color proofing systems at Xerox Corporation. Previously he was principal scientist and product manager at Isis Imaging Corporation. His research interests includes halftoning, and color management. He is a frequent presenter at IS&T conferences.