Increasing a Laser Printer's Resolution Capability Utilizing Charge Neutralization with Multiple Surface Area Exposures to Control Developed Toner Mass

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Abstract

A dramatic improvement in image quality is achieved by applying multiple surface area exposures to the photoconductive element of an electrophotographic printer to achieve more precise control of ultimate image formation on the print media than is possible using simple single exposure methods with a printer's native marking techniques. Due to the diameter of the laser beam in most electrophotographic printers today, this technique is accomplished using real-time processing with no degradation in print speed from the native marking methodology. A specific application is described and sample outputs are compared with those of a printer's native print mode.

Introduction

Resolution is, in general, a misunderstood and misused term when used to describe laser printers. A printer's resolution depends on more than the distance between successive laser scans on a photoconductor and an arbitrary spatial division in the scanning direction. (This is often referred to as addressability.) Laser beam size, toner particle size, and toner development characteristics are a few of the many parameters affecting the minimum line – space pairs that can ultimately be resolved when viewing print on media. Furthermore, resolution is one of many parameters that affect print quality, and often is not the limiting factor in the final image quality produced by an electrophotographic printer.

That said, this paper will describe a method of increasing both resolution and addressability that enables arbitrary spot placement between the centerlines of successive laser beam scans on a photoconductor. This method also allows precise control of the size of the spot, the area on a photoconductor that has been discharged to a level that will attract toner. The better controlled the size, placement, and shape of such a spot, the more precisely the image on paper will match what was intended. That degree of matching will define image quality for this discussion.

Multiple Exposure Method

The surface area charge on a photoconductor varies according to a photo induced discharge curve depending on the total light energy impinging on a particular area. This light energy depends on beam power and on the length of time that the beam exposes that area. The exposure effects are cumulative: when you expose an area that has previously been exposed, discharging will continue. This is always the case in laser printers, since the beam width is greater than the distance between scan lines. Every scan exposes both the previous and following scan areas with some light. When the surface area charge reaches a certain threshold, toner will be attracted to the discharged area. This toner is then transferred to the print medium.

A good approximation of a laser beam's cross sectional power is a Gaussian distribution. In order to achieve adequate exposure to create a desired spot (capable of attracting toner), the beam will also expose an area up to nine times the area of the spot that is created. (Note that spots are rarely circular and that they are usually formed by adjacent and overlapping exposures of successive scans. For simplicity of visualization, however, one may consider a single dot formed by one flash of a beam.) Figure 1 illustrates the exposure for a typical 1/1200 inch dot.

The multiple exposure method takes advantage of the fact that discharge is cumulative with exposure and therefore adjacent scans affect one another. Figure 2 illustrates a subthreshold exposure by itself and again combined with a stronger exposure on a successive scan line. Although the subthreshold exposure by itself does not cause enough discharge to develop toner, it does combine with the stronger exposure to move the centroid of the spot upward.

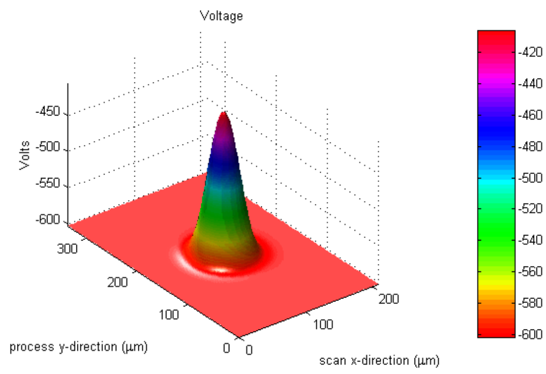

Figure 1. Single-Exposure 1/1200 Inch Dot Profile

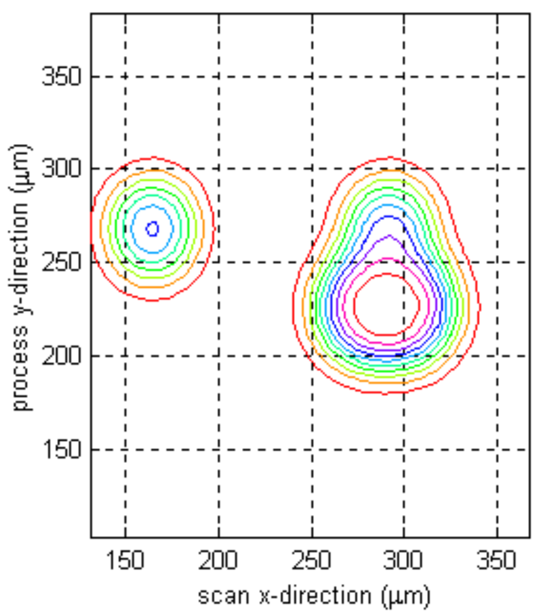

Figure 2. Multiple-Exposure Dot Formation

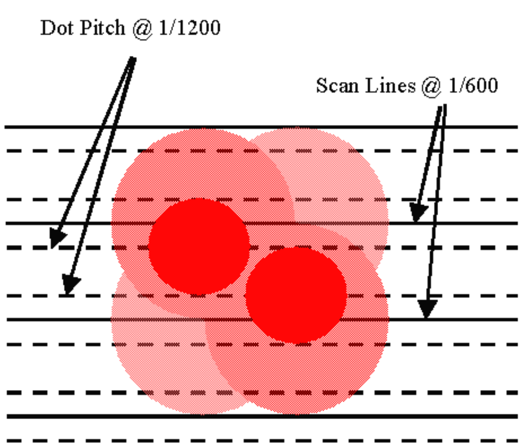

Figure 3. Multiple-Exposure Spot Position Control

Figure 3 illustrates the exposure formation for developing spots on a 1200 spot per inch (spi) grid using 600 scan per inch laser scanning. One need only move a spot's centroid 1/4 of a scan line off the main laser scan to accomplish this.

The area of the developed spot is determined by the widths of the pulses controlling the laser beam. This combination of position and area control results in increased resolution. The offset placement of the spot grid (1/4 scan line) relative to the laser scans facilitates the ability to create uniform, balanced spots, since every spot is formed in the same manner.

Determining the Exposure Modulation

Given a digital bit map, scaled to the desired spot grid vertically and horizontally, one must at a minimum consider all of the nearest pixels when determining a time value for modulation. In the vertical direction, however, not just adjacent pixels, but also adjacent laser scans will affect a given spot exposure; so one must consider pixel values yet farther away as shown by the subthreshold areas in Figure 3.

Windowing techniques are well suited for this computation, where neighboring pixel values are factored into each spot modulation. Indeed, if one can make the window small enough, translation-invariant windowed filtering (template matching) can be used. Figure 4 illustrates the relationship between laser scans and the grid locations of the digital bit map.

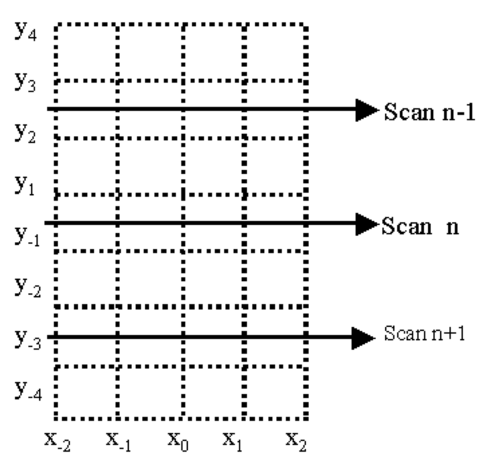

Figure 4. Bit Map Grid Relative to Scan Lines

In the current implementations, the modulation at point (x_0,y_0) is determined heuristically, based on a subset of the data points (x_i,y_j) and the characteristics of the specific print engine using the method. Specific test patterns are printed, templates are defined, and the modulation is adjusted for each data pattern to achieve the desired results.

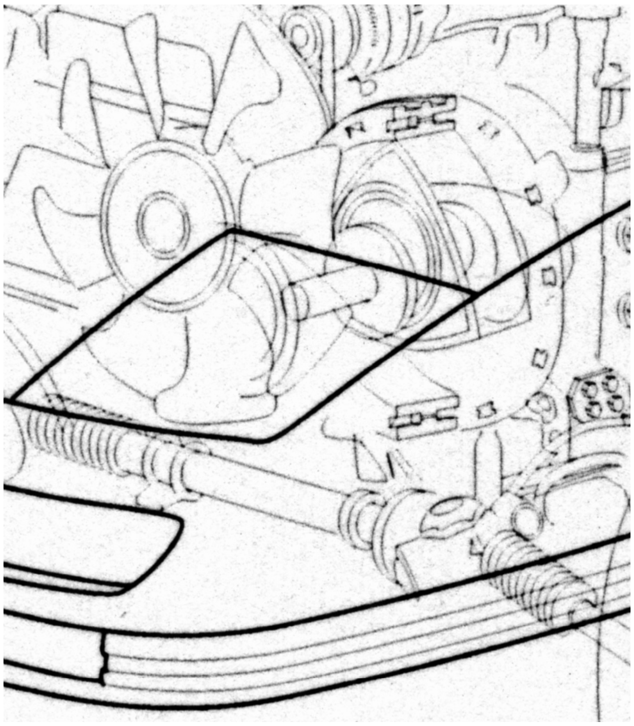

Figure 5. Optomechanical 1200 dpi Output

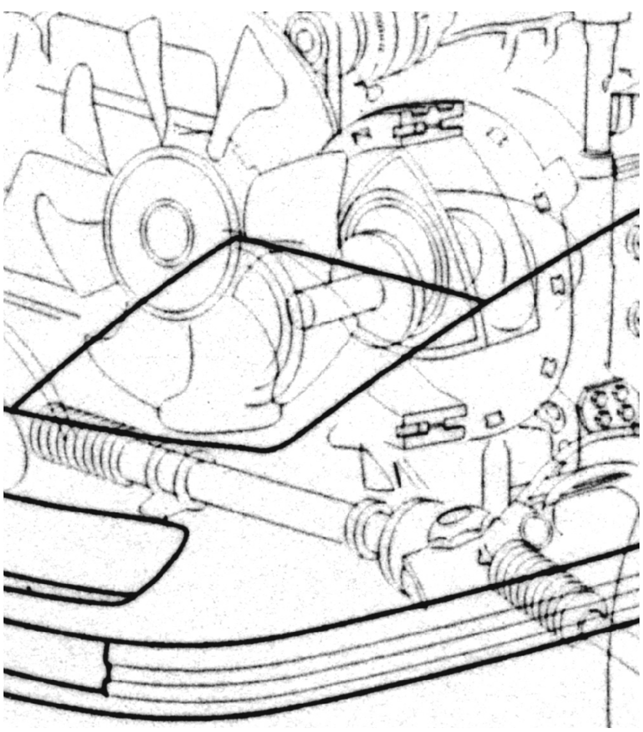

Figure 6. Multiple Exposure 1200 dpi Output

Results

The Hewlett Packard LaserJet 4050 is capable of printing with 1200 dot per inch addressability using either optomechanical means or the multiple exposure method. The benefit of using the multiple exposure method is that full-speed printing is achieved with no loss of addressability or resolution.

Figures 5 and 6 compare printed output at 5X size from the HP 4050 using both print methods.

These partial images are from the SpencerLab Printer Test Suite, printed with permission from Spencer & Associates. The fine lines are rendered as 1/1200 inch wide. Measurements both in the Hewlett Packard Company labs and in independent testing[4] have verified the equivalence of the quality of these two methods.

Conclusion

A method of controlling spot placement and size utilizing multiple exposures on successive laser scans doubles both resolution and addressability in a laser printer. With this method, a modest increase in the complexity of the circuitry driving the laser accomplishes results very similar to increasing laser scanner speed and reducing optical spot size, but at a much reduced cost and product development time. Hewlett-Packard Company holds the patents to this method.

References

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Biography

Wayne Bradburn received his B.S. degree in Electrical Engineering from Wichita State University in 1972. He co-founded DP-Tek, Inc. along with Allen Frazier. Since 1996 he has worked as a Senior Engineer/Scientist in the Advanced Technology Section at Hewlett-Packard Company in Boise, ID.

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