Black and Color Resolution Enhancement Technology used in the Hewlett-Packard DeskJet 850C Printer

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Abstract

The DeskJet 850C printer delivers a balanced PQ / performance solution to customers by applying resolution enhancement techniques to 300 dpi data when printing in “normal” modes. Black and color data both are rendered at 2 bits per pixel, yielding 4 intensity levels. Dot size is appropriate for placing up to 4 black or color drops per 300 dpi pixel. Black data is printed on 600 × 600 dpi grid locations, with edge-dot location algorithmically modified to create smoother edges. Hewlett Packard is calling the black edge-smoothing “REt”, and the multi-level bit depth “C-REt.”

The end result for the customer is quality very close to that of true 600 dpi printing, with reduced data rendering, transmission and handling overhead which greatly increases the system throughput of many documents. For those customers who desire the highest possible quality from this print engine, choosing “best” mode gives them true 600 × 600 dpi black data merged with 300 dpi / 4 level color data. Handling of this dual-resolution is now supported by PCL3, and is a key aspect of the print quality capabilities of this printer.

Introduction

With the introduction of the DeskJet 850C, HP has a product that produces near photographic image quality as well as offering significant user convenience with high throughput and 600 dpi black text on both plain and glossy paper.

Printheads

The black print cartridge for the DeskJet 850C is a true 600 dpi printer which sets new performance levels for throughput, quality, and user convenience[1]. This printhead has 300 orifices, three times the number on the 1200C cartridge, and operates at 12 kHz. Advances in the control logic on the printhead allow 300 orifices to be operated with only 52 connections. In addition, this cartridge uses a new black pigmented ink for very high print quality. Orifices are fabricated by excimer laser ablation directly in the same polyimide layer which forms the substrate for the interconnect flex circuit, compared to the gold-plated electroformed nickel orifice plates used in earlier HP printheads. The volume of the ejected ink drop is 35 pL.

The color printhead for the DeskJet 850C is a 300 dpi cyan / magenta / yellow printer with 64 orifices per color. The 192 orifices are operated with only 52 connections. The inks are dye-based, and offer a larger color gamut than previous HP color inks. This is the first Hewlett Packard printhead to offer grayscale printing—for each of the three subtractive color primaries, it can print 4 distinct levels of optical density (white plus three levels of color) in each 300 dpi pixel.

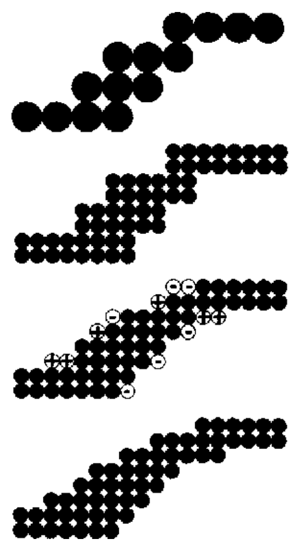

Figure 1. REt processing sequence: (a) original 300 × 300 dpi data, (b) simple 2 × expansion from 300 dpi to 600 dpi, (c) REt algorithms applied, (d) 600 dpi image after REt

Resolution Enhancement Technology

REt optimizes black edge sharpness and smoothness in text and graphics by making use of the full 600 dpi

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addressability of the black printhead in the HP DeskJet 850C printer. REt applies a collection of rules to add and delete dots to produce a high-quality rendering. In Figure 1, a portion of an actual printed character is used as an example for 600 × 600dpi REt printing with 300dpi image data. First, the 300dpi image is sent to the printer. This significantly reduces the amount of data the host must generate and communicate to the printer compared to a full 600dpi bit-map. Next, REt performs a simple 300dpi to 600dpi expansion. The edge effects of 300 dpi dots on 300 dpi centers is still apparent. Finally, REt rules are applied in the neighborhood of each 600 dpi dot to add or remove neighboring dots to a true 600 dpi rendering of the original data with smooth, sharp edges.

REt provides true 600 × 600 dpi quality in text and black graphics while minimizing the amount of computation and communication by the host. This produces higher document throughput for bit-mapped images and requires less printer memory. REt enables HP to reduce the cost of the printer while providing higher throughput and print quality.

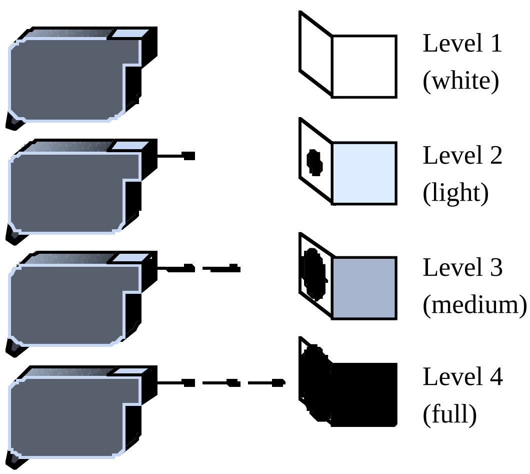

Figure 2. C-REt uses small drop volume and multiple drops at 300 dpi to achieve 4 levels per pixel

Color Resolution Enhancement Technology

Color Resolution Enhancement technology, or C-REt, is HP's new halftone color printing technology introduced with the 850C. In conventional ink-jet color printing, only two levels per pixel are achieved: level-1 is with nothing printed, and level-2 is with a single drop of primary color (cyan, magenta, yellow, or black). The drop volume of the primary colors is chosen to completely fill the pixel at the printing resolution leaving no white space. In the DeskJet 850C, small drop volumes of primary colors are used to achieve four levels per pixel (see Figure 2). As before, level-1 is with no ink. Level-2 has a single small drop producing a light color (with white space in the pixel along with the colored spot). Level-3 with two drops has a large color spot and less white space producing a medium density. Level-4 with three drops produces a fully-saturated primary with no white space. In this manner, C-REt achieves four-levels of the color primaries at 300 dpi resolution.

In addition to four levels of each color primary, cyan, magenta, and yellow, the DeskJet 850C uses its 600 dpi black printer to print five levels of black in a 300 × 300 dpi dither pattern. This allows smoother gray halftones at 300 dpi.

In conventional ink-jet printing, the secondary colors, red, green, and blue, are created from two drops of primary colors per pixel. Thus, a binary color printer can print eight (8) colors in each pixel: white, cyan, magenta, yellow, red, green, blue, and black. C-REt allows many more directly printable colors and gray-levels. A pixel can be printed with a light red (red + white) with a magenta and yellow drop. An orange can be printed with a magenta and two drops of yellow. A full red can be printed with two drops each of magenta and yellow. With various combinations of the three color primaries and black, light to fully-saturated to grayed primaries and secondaries can be printed as well as intermediate hues. C-REt can directly print about thirty (30) distinct colors per pixel compared to only eight (8) using conventional binary-level color printing.

Full color images and desktop publishing images usually contain many more colors than are directly printable. These intermediate colors are created by color halftone dither patterns, which combine groups of pixels of the printable colors. This produces an approximation to the desired color over the range of a few pixels, but this can introduce visible textures (or graininess). To some extent, texture can be minimized by proper choice of halftone algorithm, and this depends on what kind of image is being printed. Some algorithms work best for natural images (scanned photographs), while others are preferred for color text, color business graphics, and line art. Most printer drivers give the user a choice of halftone method, while HP's ColorSmart printer driver can automatically chose the best method depending on what kind of image is printed.

Because C-REt prints more colors per pixel than conventional binary ink jet printers, closer approximation to the desired color is achieved at the full printer resolution. This means that dither patterns have less texture, because the error is smaller between the desired color and the printable color in each small group of pixels. Minimizing the color error improves the performance of halftone algorithms resulting in smoother transitions between highlight and shadow. This is especially important in reproducing skin tones. C-REt is also optimized for various media, such as transparency film, plain paper, and special paper. In each case, C-REt achieves the greatest number of printable colors by adjusting the number of drops of ink that can be printed in each pixel. Halftone color printing at 300 dpi offers both high printing throughput and the image quality of higher resolution: the 850C can print a full color page with C-REt in less than two minutes. And, C-REt produces vivid color on plain paper, special paper, and overhead transparency film. With C-REt at 300 dpi, the complexity of printhead and driver electronics and the amount of image data to be generated and communicated by the host is reduced. The reduction of printer hardware, in terms of processor and memory, translates into a lower-cost, high- performance color printer.

Throughput

The throughput of the DeskJet 850C is dependent on document content because different print modes are used depending on quality level, and the arrangement of text, graphics, and color. The time is also different for the first page and subsequent pages (especially copies) due to printhead servicing, I/O, and raster processing considerations. That is why manufacturers and product test laboratories often use standard pages of text, mixed black text and graphics, and mixed text and color graphics to rate and compare printers.

For printing black text, the speed is 4.5 ppm for “normal” mode, or 3.2 ppm for “best” mode. The 850C printhead can print three full rows of text at a time. If there is sufficient whitespace, called “leading,” between the rows of characters, the printhead can print bi-directionally: the first three lines are printed left-to-right and the next three right-to-left. No time is lost returning the printhead right-to-left after the first pass. The trick here is that very small misalignments (a fraction of a dot diameter) between neighboring swaths of pixels printed the left-to-right and right-to-left lines will be invisible to the eye.

When no whitespace exists between swaths, the printhead must be scanned unidirectionally. This is because the eye is exceptionally good at seeing tiny offsets in vertical (and horizontal) black lines. An offset that runs through the middle of a line of characters even less than 1/1200 inch is visible and gives the text an *italic* or slanted appearance. When printing unidirectionally, the throughput drops nearly 50% because the printhead does not print on the retrace. In general, the processor examines the pixel buffer (or character stream) for each swath and determines bi- or uni-directional printing on a swath-by-swath basis to maximize throughput. The appearance of certain characters like “|” or the line-drawing symbols (i.e., ╠, ╬, ╔, etc.) which extend across the whitespace between lines trigger unidirectional scans.

When printing color, throughput is 1.0 ppm in “normal” mode and 0.7 ppm in “best” mode. Color is printed unidirectionally rather than bidirectionally to achieve consistency in the fixing mechanism: the interaction of liquid ink with paper or overhead transparency film. Secondary colors in HP ink jet printers are produced “dot-on-dot.” That means that a pixel is colored blue (B) by first printing a cyan (C) drop followed by a magenta drop (M) in the same location: $C + M = B$. The blue produced by this process is not precisely the same blue you would get by printing a magenta drop first followed by a cyan drop ($M + C$). So, $C + M \neq M + C$. The reason is the fixing process is slightly different for each drop sequence: the first drop interacts with a dry media surface and it spreads and penetrates differently than the drop landing on an area already wet with ink. Unidirectional printing forms the secondary colors C + M = Blue, C + Y = Green, and M + Y = Red in the same sequence on each scan assuring color consistency.

The fixing mechanism requires a certain time to complete, so as the printhead is completing a swath (say left-to-right), the ink at the beginning of the swath has spread and penetrated the paper (“dry”) while at the end of the swath that process is still underway (“wet”). In unidirectional printing, there is a consistent swath-to-swath time allowing the fixing process to complete to the same point each time a “wet” pixel is placed near (or on) a “dry” one. If the printhead operates bidirectionally, then there would be “wet” on “wet” neighbors at the beginning of the next swath but “wet” on “dry” at the end. This would appear as different drop spread and color bleed characteristics across the image and cause visible bands. To maximize throughput, the printer operates bidirectionally when it can print black text and unidirectionally in color areas.

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References

1. P. H. McClelland, “New Directions in Print Head Construction”, Proceedings of the Eleventh International Congress on Advances in Non-Impact Printing Technologies.
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