

High Quality Imaging System for Color Inkjet Printers Using a Piezoelectric Print Head

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Abstract

A high quality imaging technology has been developed for color inkjet printers using a piezoelectric print head. In this technology, we used the MLChips head to eject micro droplets in the most suitable placements and added a lower density ink in the cyan and magenta color components for the reproduction of highlight areas. In addition to this hardware technology, we developed halftone algorithms to obtain smoother gradation output. This new technology greatly improves the graininess of the image and achieves very high quality images.

Introduction

The demand for higher image quality from color inkjet printers has intensified along with the explosion in recent years of color digital images. The human eye is able to distinguish very fine gradations in areas of an image having low spatial frequency and is even more sensitive to graininess around highlights. Inkjet printers of the past were not able to wholly overcome these characteristics of human sight. But remarkable progress has been made in recent years, and technical innovations in all kinds of printing methods means that today's color inkjet printers can offer high image quality.

This paper examines an inkjet printing system for high quality image output. It discusses hardware technology, centering on a print head utilizing a piezoelectric element, as well as the software technology needed to get the most out of the hardware.

Investigation Method (Hardware Technology)

In general, dot graininess on recording paper can be approximated as the product of ink weight, which determines dot size, and ink density. Therefore, we investigated a means of reducing the graininess of the dots themselves by controlling both of these factors.

Investigation into the Generation of Micro Dots

EPSON inkjet printers record on a printing medium by means of a method that uses piezoelectric elements in the print head. In this study we sought to make the dots smaller by using what is commonly referred to as MLChips (Multi Layer Ceramic with hyper integrating piezo segment)[1]. Figure 1 shows the structure of the MLChips print head. This print head consists primarily of the ink chamber, vibrating plate, and piezo element, all of which have been laminated together to form an integrated structure. The total thickness of the print head, from the top of the upper electrode to the end of the nozzle shown in the figure, is approximately 0.5 mm. The design of each component has been optimized to allow the head to eject smaller dots. The entire structure and its physical properties, from the shape of the nozzle and ink supply port, to the capacity of the ink chamber and the resiliency of area around the chamber, have an effect on the amount of ink dots expelled.

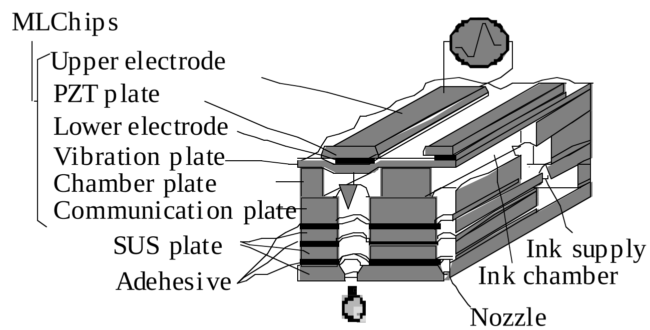


Figure 1: The composition of MLChips type head

However, further reducing the diameter of the nozzles, one of the factors that determines the volume of dot ejection, is effective only to a point. Nozzles that are too narrow tend to clog with ink and have other problems that lead to reduced reliability. The size of ink droplets fired can also be reduced by lowering driving voltage, but lowering the driving voltage also lowers the ejection speed, and accurate ink flight cannot be ensured. Therefore, we researched a means of accurately firing smaller droplets of ink from nozzles having the conventional diameter.

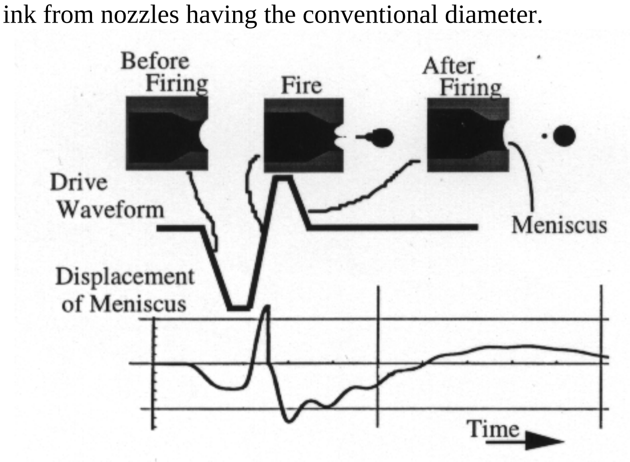


Figure 2: Meniscus control system

Figure 2 shows a meniscus (the curved upper surface of the ink formed on the tip of the nozzle) control system. Prior to being fired, the meniscus is retracted to a predetermined position away from the tip of the nozzle. By rapidly firing the ink from that position, it is possible to form ink droplets that are both small and expelled at a high rate of speed. This method enabled the firing of very fine droplets at an ejection rate that does not present problems in terms of ink flight. In addition, we were able to improve ink drop cutoff and suppress residual vibration generated in the meniscus by again lowering the driving voltage after ink ejection. This also leads to higher head driving frequency.

Investigation into Lower Density Ink

Because they have a lower lightness than yellow, dots of cyan ink and magenta ink tend to be more conspicuous. To combat this problem, therefore, we tried using lower density cyan and magenta inks together with the conventional normal density inks. The reason for this joint usage was to prevent the ink from bleeding on the recording paper, which is one of the fundamental problems that must be addressed with inkjet printers. Joint use of lower density and normal density inks had been tried in the past [(2)], and some lower density inks were actually commercialized. However, these inks failed to break into the mainstream. This failure to gain dominance may have been because with the technology available at the time the more effective means of improving image quality was to strive for higher resolution.

Figure 3 shows the relationship between input level and dot share when lower density ink and normal density ink are used together. The yellow ink in this graph is processed in the conventional way. In the highlighted areas, which have a low level of input data, more dots of lower density ink are printed than in conventional printing. The effect of recording a higher number of lower density ink dots is to improve real resolution while reducing the graininess. In addition, when establishing the density of lower density ink, it is necessary to take into account the grain characteristics of lower density ink in the highlighted areas as well as the grain characteristics of the normal density ink that will be interspersed within it. The key to achieving the appropriate balance of ink density and its effective use is in the algorithms. In this investigation, balance was maintained by setting the density of the lower density ink at approximately one-fourth that of the normal density ink.

The Effect of Hardware Technology Improvements

Figure 4 shows the results of a test on the recognition of dots recorded in highlighted areas. The micro dots, which have a far smaller weight than convention ink, also have a very small dot surface area, which is effective in reducing the graininess. Moreover, using lower density ink achieves a grain in which dots are indecipherable at a viewing distance of 30 cm. These technologies are employed in the Epson Stylus Photo series of color inkjet printers. To obtain the same grain using normal density ink alone, the ink volume would have to be at least one-third to one-fourth that of the micro dots, and higher resolution printouts would be achieved at the expense of printing time. One can see, therefore, that the joint use of normal and lower density inks is advantageous from a perspective of both image quality and printing time.

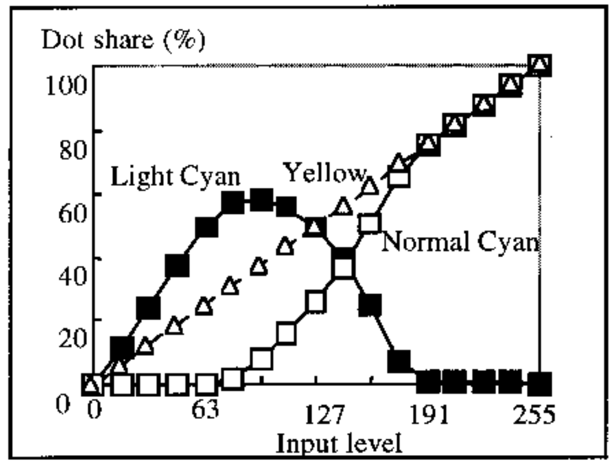


Figure 3: The image of relation between input level and dot share (%)

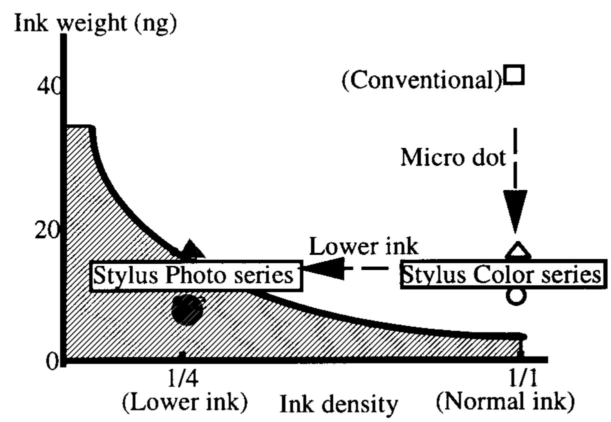


Figure 4: The result of dot recognition at Photo paper (Shadow area : no recognized dots by L=30cm)

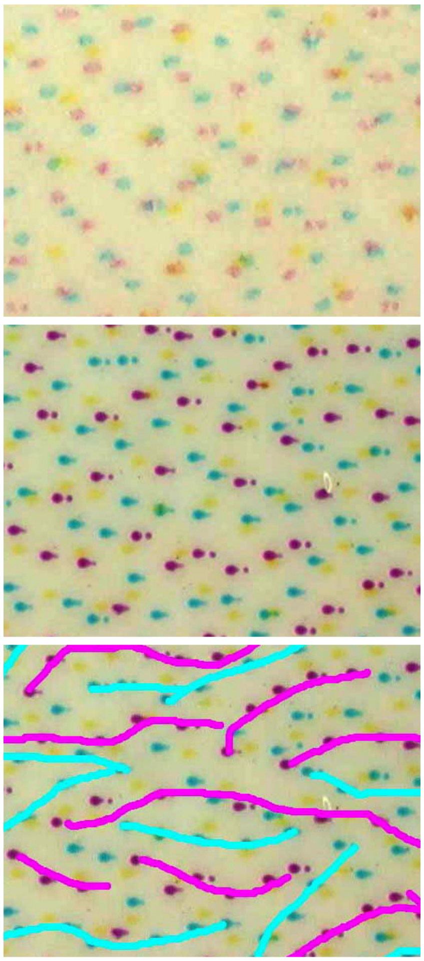
Investigation Method (Software Technology)

Even if hardware technology is able to reduce the graininess of each individual dot, unless adjacent dots are applied in the appropriate position on the page, conglomerations of dots will be recognized as noise. Therefore, a halftone algorithm that arranges dots in the optimum location plays an important role in reducing the graininess and achieving smooth gradations.

Dot Distribution in Highlighted Areas

The enlarged photographs in Figure 5 show a comparison of dots in a highlighted area. When dots occur in the locations shown in photograph (b), the cyan and magenta dots appear to be the same dot and are dispersed by the same process. In this type of case, as shown in photograph (c), the cyan or magenta dots become linked to form "worms" , which are registered as noise by the eye.

Not only the distribution of dots of each color but the distribution of dots of intermediate colors must also be optimized in accordance with dot placement density. To achieve this, the dithering matrix and error diffusion conditions must be optimized for each color. However, the specific method for achieving this involves elements connected with the recording method and other hardware conditions, and further fine adjustment is required.



(a) Stylus Photo series

(b) comparative sample

(c) worms from (b) image

Figure 5: Enlarged photographs of recorded dots on different printers (C: Tracing the dots like viewing a star constellation joins them into a "worm")

Gradation Reproducibility in Highlighted Areas

To produce photo quality images, a full-color inkjet printer must be able to accurately reproduce each color level for 8-bit RGB color data, the most common data input. After color correction conversion processing and gamma correction processing are performed from the input data, the 8 bits of each color must be maintained at the stage prior to halftone processing in common algorithms that perform halftone processing (to generated each color of dot). These halftone algorithms therefore require design improvements. It is not possible to show the specifics of the method used in the current investigation, but under conditions where the image processing time did not interfere with recording speed, the algorithms were optimized to produce smooth halftones. The graph in Figure 6 plots the results of lightness measurements when input was changed for each level in a gray scale highlight area; it also shows the light cyan dot percentage actually printed by a Stylus Photo series inkjet printer. In the comparative output sample the output level is the same for several levels of input data. In the Stylus Photo series output sample, however, the number of dots recorded in each level maintains a smooth output.

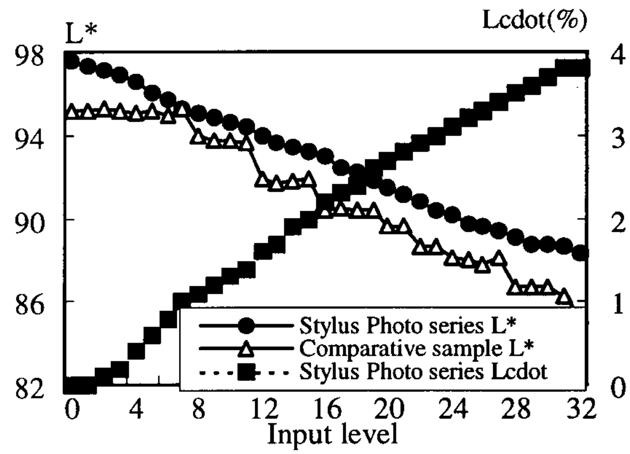


Figure 6: The result of gradation control in highlight area

Conclusion

1. The accurate firing of micro droplets requires precise control of the processes involved in the firing operation. The piezoelectric print head lends itself very well to such precise control.
2. The use of lower density ink micro dots is highly effective in reducing the graininess.
3. The joint use of lower density ink and normal density ink provides outstanding balance for color inkjet printers.
4. Software technology that complements the performance of the hardware technology is critical for achieving photo-quality images.

References

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2. Udagawa: The trend of Bideo (Pictorial) Color Hard Copy: *Journal of the Society of Photographic Science and Technology of Japan*, **50**, vol **1** ,1987 (in Japanese)