General Alignment Strategy of InkJet Devices

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Abstract

A variety of error sources can produce print quality defects in the Drop on Demand Printers. The misalignment between drops (from same or different color) produces bad line reproduction, or shadows in the text or images. The misalignment errors have many different sources (color to color, bidirectional movements, mechanical errors, etc). The systems used to correct those misalignments were implemented since the very beginning of the printer market, and almost all of them are based in print some features (patterns) design to isolate the error over the output media, measure those features and extract the correction needed to compensate it.[1] Those alignments were time and paper consuming.

This paper will present a new strategy based in the general approach of the PQ defect to correct the misalignments of the Inkjet Printers with less demanding in time and paper wasted.

The system use a single pattern that is measure to obtain geometrical positions of certain marks in it. The positions recorded are mathematically treated to isolate and obtain the error produce by every source of error, this error value are use by the printing system to correct it and produce the optimal output quality.

The advantage of this system can be applied to other printing system based in multiple writing systems (inkjet, laser, etc.)

Introduction

The Digital printing technologies are almost everywhere. You can find from color portable printers (pages per minute) up to big digital presses (thousands pages per minutes).

All this system has some things in common. One of those points are the necessity of have some mechanism to control the color registration and other defects.

Figure 1. Color text misaligns.

From the origin of the printing industry, many systems were development to solve those problems.

In the case of the InkJet Technology, this effect is worse, due to the way the printing heads are design and the way the image is create.

Print Head Structure

The HP InkJet print head typical structure shows two rows of drop firing devices (nozzle).

Every row presents nozzle spacing half the printing resolution (300dpi). To form a vertical line the two rows should be place in the same position.

The different print heads are attached to the mechanical unit (carriage) that move over the media. The combining movement of the carriage and the paper forms the image.

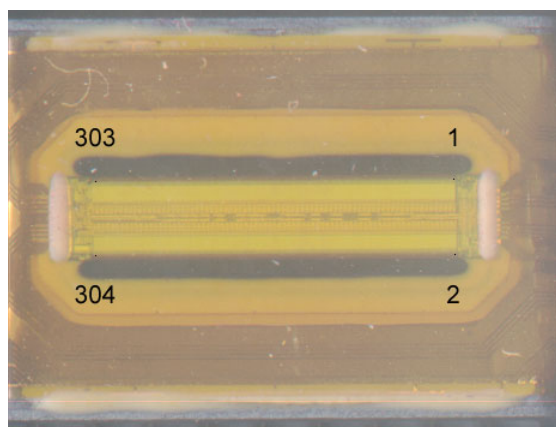

Figure 2. HP print head

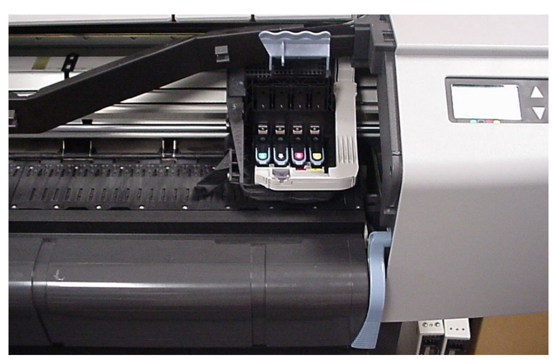

Figure 3. Printer Carriage with 4 print heads

Image Formation

To reduce the printing time, the carriage prints in both directions, introducing additional errors.

To hide bad nozzles the image is form using multiple passes over the media in order to random mix the nozzle contribution.

Along the different InkJet generations, the number of nozzles inside a printer, because the number of nozzles in the print head and the number of print head in the carriage, is increasing as can be seen in Fig 4 (including the pattern size).

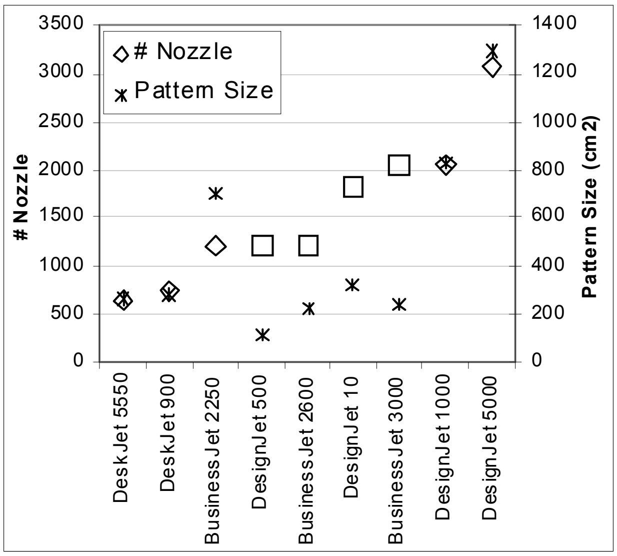

Figure 4. Number of nozzles

The way of correcting those effects has been changed becoming more and more complex, and automatized. The first printers used patterns printed that need to be ranked by the user who introduces the correcting values. These systems are open-loop (since the correcting procedure need a printer external intervention). The need for an automatic correction system was addressed using different systems, the most common is the use of an optical sensor that read the patterns and calculates the correction factors.[2]

Table 1. Parameters to correct and sources (some examples).

Parameter	Type
Odd-Even	Print head
Color to Color	Print head
Bidirectional	Image Formation
Nozzle shape	Print head
Θx,y,z	Print head

Logically, increasing the number of factors to be corrected and the numbers of nozzles to be aligned implies bigger size of the alignment pattern.

Traditional Alignment Process

When the system (or user) triggers an align procedure, the printer prints a pattern, measures the pattern with the optical (or other type) sensor, calculates the correction parameter and applies it. This process iterates over all the parameters to correct[2] in the printer.

Every pattern is specially designed to highlight the parameter to be corrected. The size of the pattern depends on the number of nozzles of the print heads.

The pattern is measured by the sensor. In the printers with external (user) intervention, the measure action is taken by the user and is feedback to the printer through the driver or front panel.

The printer calculates the value necessary to correct the parameter. By the end of the process, those corrections are applied to optimize the print quality. This implies that the pattern size is increasing with number of nozzles of the printer and the number of parameters to correct.

Another point is the time taken to complete the full alignment of the printer. This depends on the number of parameters, the number of nozzles per print heads, the number of print heads inside the carriage and the speed of measuring and calculating the corrections. When the number of nozzles increase, the size and time to complete the alignment become unpractical (see Table 1).

New Alignment Strategy

The basis for the new alignment is to change the architectural approach to the printer alignment.

The underlying thesis in the old alignment is to print every pattern under the conditions that need to be corrected. The new align sets a pattern that contains all the possible printing conditions. If the printer has no printing errors this pattern were exactly equal as the theoretical pattern. The errors introduce shifts in the position of the pattern that can be measured and compared with the theoretical one. The set of error in the pattern can be used mathematically to find the correction factors to be implemented.[3]

It does not create a special pattern for every correction, but it creates a general pattern that covers all the printing conditions. In this way all the possible correction factors can be measured and corrected. The idea is "Print only one pattern that can be used to calculate all the parameters needed". Measure one time and calculate as much correction factors as needed.

The pattern reflects all the printing conditions of the printer. Every row of nozzles in the print head is grouped by addresses. With this division a pattern is created in all printing conditions. The basic pattern cell is in Fig 5. This fundamental cell is printed at one carriage velocity.

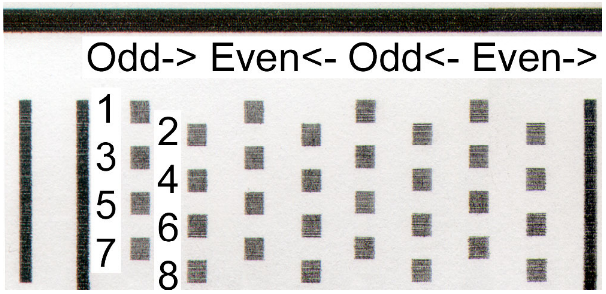

Figure 5. Fundamental Alignment Cell

The full alignment pattern is created repeating this pattern in all the colors, printing velocities and repetitions (if needed). Fig. 6.

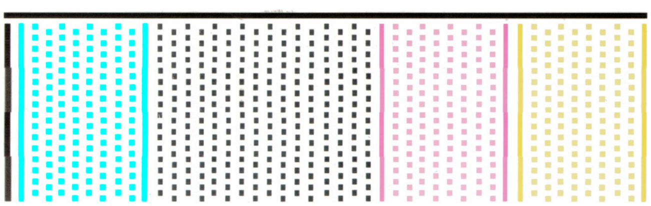

Figure 6. Alignment Pattern (HP DesignJet 500)

By the pattern construction, we know the theoretical position of every address:

$$theo\_pos_{pen,add,OE,dir,vel} \quad (1)$$

The subscript indicate color or pen inside carriage (pen), print head address number (add), print head row (OE), printing direction (dir) and velocity of printing. If additional printing conditions are needed the pattern are modified to incorporate the new conditions and the new index are added to the error matrix.

When the pattern is measured (with optical sensor or other systems) the real position is tabulated:

$$real\_pos_{pen,add,OE,dir,vel} \quad (2)$$

We calculate the error in the printing process as the differences between the theoretical and the real position

$$err_{pen,add,OE,dir,vel} = theo\_pos_{pen,add,OE,dir,vel} - real\_pos_{pen,add,OE,dir,vel} \quad (3)$$

This error matrix is then used to calculate the correction factors for the printer.

Some example. The bidirectional correction (depending on pen and velocity) is:

$$Bidir_{pen,vel} = \sum_{add,OE} \left(err_{pen,add,OE,<-,vel} - err_{pen,add,OE,->,vel} \right) \quad (4)$$

The pen to pen align (depending on color, velocity and direction) is:

$$(Pen_1 Pen_2)_{dir,vel} = \sum_{add,OE} \left(err_{2,add,OE,dir,vel} - err_{1,add,OE,dir,vel} \right) \quad (5)$$

In similar manner, the rest of the other parameters can be calculated.

The pattern size is independent of the number of correction parameters, depending only in the nozzle number of the print heads.

Comparison

One of the possible comparisons is the size of the alignment pattern with every algorithm.

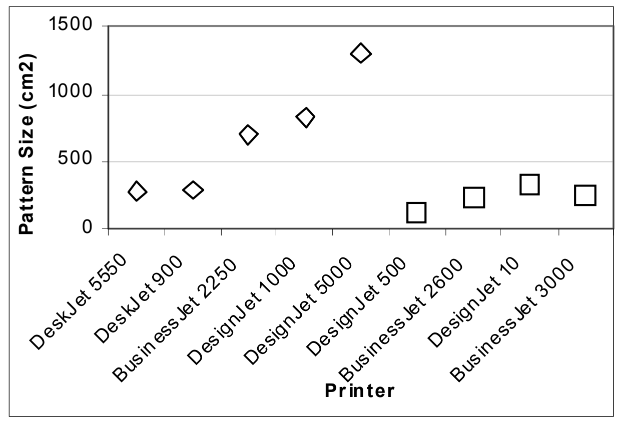

Figure 7. Size of alignment Pattern of different printers

Here the first 5 printers are using the old alignment, and the last 4 printers uses the new one. The different populations can be seen, but it is not clear. A better separation can be defined if we take into account that some printers align a few parameters, while others align many. In the table 1 you can see the different tables and align parameters.

Table 1. Printers, Number of parameters to correct and size of the align pattern.

PRINTER	Parameters	Size (cm^2)	Time (s)
Old Alignment			
DeskJet 5550	6	266	90
DeskJet 900	4	285	90
BusinessJet 2250	23	696	314
DesignJet 1000	35	825	456
DesignJet 5000	389	1298	1050
New Alignment			
DesignJet 500	416	114	270
BusinessJet 2600	416	224	368
DesignJet 10	816	322	482
BusinessJet 3000	792	240	260

As it can be seen, there is a gap in the number of parameters to correct, including DesignJet 5000 with old pattern, this is due to the new pen architectures correction possibilities.

If we plot the pattern size versus the number of correcting parameters (fig 8) the differences between the two align strategies are clear. This new alignment procedure uses seven times less size in the alignment pattern than the old one. If we need to align the 792 parameters with the old procedure, we will need three A-size sheets.

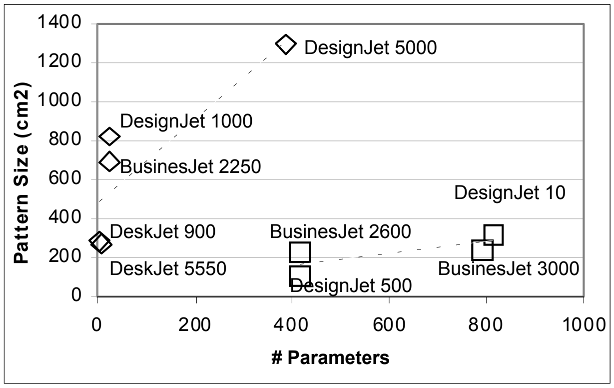

Figure 8. Pattern Size vs. Number of Parameters

Another point of advantage is the time to complete the alignment. In the old alignment every correction factor needs a separate pattern with the time to print and measure the pattern. This time depends on the number of factors to be corrected in every printer.

A better metrics is the time efficiency, the ratio between the numbers of parameters over the time to align. With this metric the differences between the two align procedures are clear. The new alignment is 15 times more efficient compare with the old one (Fig. 9).

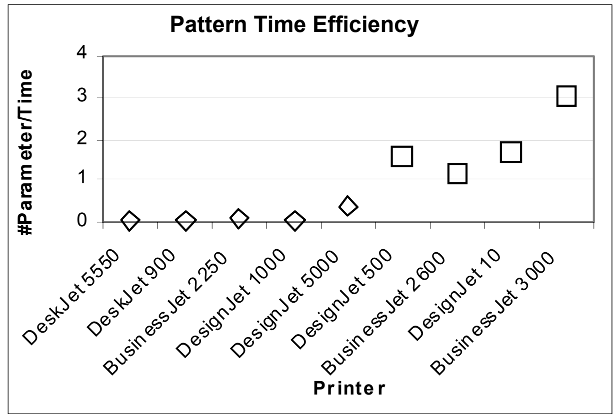

Figure 9. Time efficiency of aligns.

Conclusion

A new alignment procedure for a drop on demand printers is presented, that demonstrate a better efficiency on size of media used and the time to complete the alignment.

Comparison has been done between the old and new alignments in the Hewlett-Packard printers, but the generality of the system allows implement it over other printing technologies because the system is technologically independent.

References

1. Helmut Kipphan, Handbook of Print Media, Springer, 2001, pg. 108,307.
2. Robert D. Haselby et al., *Automatic print cartridge alignment sensor system*, U.S. patent 5.289.208, (1994).
3. Jorge Castaño et al., *Techniques for Measuring the Position of Marks on Media and for Align InkJet Devices*, U.E. patent 1,176,802 (2000).

Biography

Jorge Castaño received his M.S. degree in Physics from *Universidad Autonoma de Madrid* in 1990. He cursed PhD. studies in *Universidad Complutense de Madrid* working in surface physical chemistry and designing optical sensing system for industry research groups and computer-aided imaging for scientific and medical applications, since 1995 he has worked in the Barcelona site at Hewlett-Packard in Sant Cugat, Spain. His work in Writing System and Image Quality Research & Development of different HP DesignJet and BusinessJet Printer series, having several patents on this field.