Software Alignable Printheads

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Abstract

Alignment of nozzles within a printhead and between interlaced printheads is implemented with software. The z-profile design of the printhead enables compact arrays. Actuators (Silicon MEMS die with drop ejectors) are positioned within a printhead so that an overlapping region with a vernier scale guarantees 2 nozzles will be aligned inside the overlapping region to within 1 μm. The rows of nozzles in each actuator have three different regions: the normal 1200 npi pitch region (21.166 μm nozzle spacing) in the center, the lower pitch region at one end, and the higher pitch region at the other end. Two consecutive actuators (either inside a printhead or in adjacent printheads) are placed such that the lower pitch region of one of them overlaps with the higher pitch region of the other. By jetting with appropriate nozzles in the overlap region, a smooth transition in the printed pixels is achieved and expensive, time-consuming mechanical alignment is eliminated.

Introduction

This design has been implemented in the new Xaar 5601 GS3 printhead. This printhead is a 1200 dpi printhead which can be used in single colour mode at 1200 dpi and in two colour mode at 600 dpi.

The implementation of this design requires having a means to find the two best aligned nozzles in the overlap region. Nozzles in the first printhead are not used after the cross over point, conversely nozzles in the second printhead are not used before.

As a result of this design, some technical considerations need to be addressed:

1. Variation of print optical density in the area with the vernier as a consequence of the differences in pitch.
2. Variable printhead sizes as a consequence of the variation in the first and last printing nozzle positions.
3. The design has to work in 1200 dpi and in 600 dpi modes.
4. This implementation solves the problem of printhead alignment in the printhead direction .To fully align by software, the problem of aligning printheads in the process direction must be addressed as well. Fortunately this does not require any specific feature in the printhead. One can adjust the timing between rows of nozzles or shift when pixels are printed.

In this paper we are going to address only one possible implementation to find the two best aligned nozzles in the overlap region, how to correct small variations of optical density in the area with the vernier and an example of image manipulation at pixel level to correct misalignments in the process direction.

Printhead axes

The printhead axes, as used in this document, can be seen in Figure 1. The X axis is the printhead direction; in a single pass printer it would be the direction of the printbar. The Y axis is the process direction, perpendicular to the X axis; in a single pass printer it would be the direction of the media movement. The Z axis is the drop ejection direction, perpendicular to the X and the Y axes.

The vernier arrangement

The Xaar 5601 GS3 printhead is made out of four actuators. Each row of nozzles in each actuator has three distinct areas defined by their nozzle pitch. A main area, with nozzles spaced at a nominal pitch in the centre (nominal pitch is 21.166 µm, corresponding to 1200 npi), a short lower pitch area at one end, and a short higher pitch area at the other end. This arrangement can be seen in Figure 1.

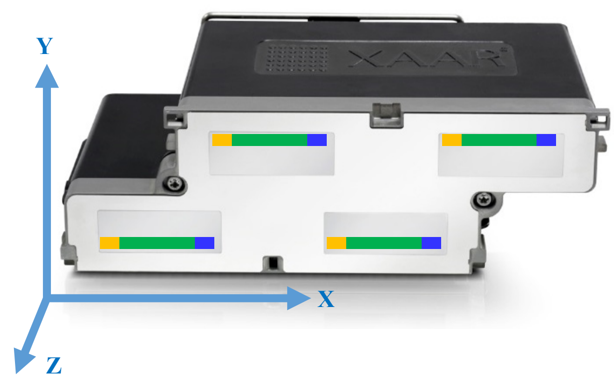

***Figure 1**. Image of the Xaar 5601 GS3 printhead showing its four actuators. In green, the nominal nozzle pitch area; in yellow, the lower nozzle pitch area; in blue, the higher nozzle pitch area. Each actuator overlaps in a small region with the actuator next to it. The overlap area is made out of the lower nozzle pitch area from one actuator and of the higher nozzle pitch area from the other actuator. The printhead axes are shown for reference. The X axis extends along the printhead, the Y axis along the process direction, and the Z axis along the drop ejection direction.*

***Figure 2**. As in Figure 1 for actuators inside a printhead, the vernier arrangement works for actuators in adjacent printheads. A vernier design, as implemented in the Xaar 5601 GS3 printhead guarantees that 2 nozzles will be aligned inside the overlapping region to within 1um*

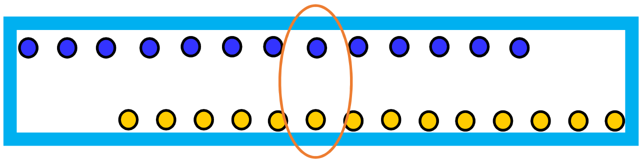

Figure 3*. Vernier nozzle arrangement shown schematically. The blue row of nozzles at the top show the higher nozzle pitch area from one actuator and the yellow row of nozzles at the bottom show the lower nozzle pitch area from another actuator (perhaps in a different printhead). The crossover point is shown around the two nozzles that are best aligned in the X direction.*

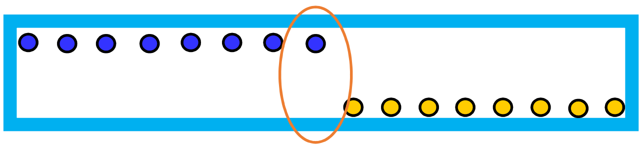

Figure 4*. Nozzles in the 1st printhead are not used after the cross over point, conversely nozzles in the 2nd are not used before.*

Finding the best aligned nozzles

The best aligned nozzles in the overlap region can be found, for instance, by simply printing a set of flat images using different nozzles as the "ideal" alignment. Some of them will produce a dark area in the overlap region, others will produce a light area in the overlap region, and the optimum nozzles will produce a flat image across the overlap region. In Figure 5 there is an example of such a pattern for two actuators that are perfectly aligned mechanically. The best image quality is obtained, then, by choosing to switch printing from the first actuator to the second somewhere between nozzles 24 and 28 of the overlap. To the left of the optimum white areas can be seen, while to the right of the optimum dark areas are visible.

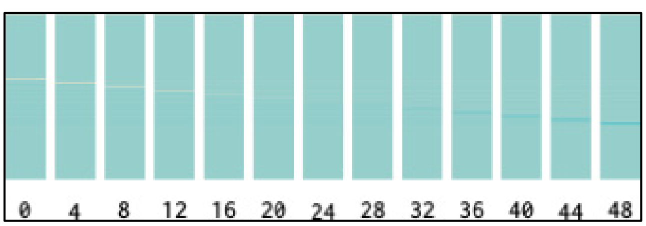

Figure 5*. Example of a flat density area printed by two actuators that are perfectly aligned mechanically, when the top part of the pattern is printed by one actuator and the bottom part is printed by the second actuator and the nozzle in the overlap area at which printing switches from actuator one to actuator two varies from 0 to 48. The best image quality is achieved when the switching nozzle is chosen between 24 and 28 (this is a consequence of the perfect mechanical alignment). If the switching nozzle is chosen below 24, a white gap appears. If the switching nozzle is chosen above 28, a dark band appears. This image is magnified 5 times.*

When the actuators are not so well aligned mechanically, the optimum switching nozzle moves either to the left or to the right, but the process to align and the final achievable image quality remains the same. In Figures 6 and 7 the behaviour in the case of -20 µm and +20 µm of mechanical misalignment is shown.

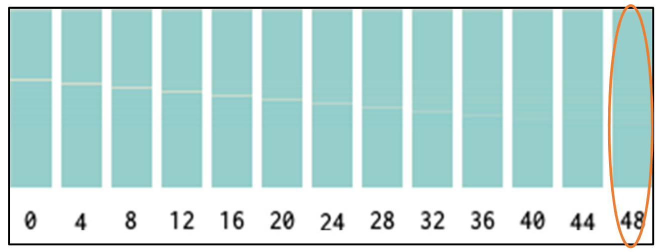

Figure 6*. Example of the same pattern as in Figure 5, but printed by two actuators that are not perfectly aligned mechanically. The mechanical misalignment is -20 μm. The optimum image quality is achieved by choosing nozzle 48 as crossover point. This image is magnified 5 times.*

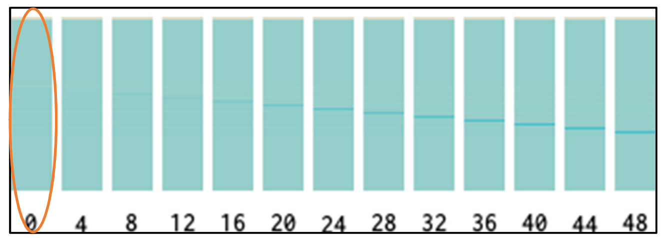

Figure 7*. Example of the same pattern as in Figure 5, but printed by two actuators that are not perfectly aligned mechanically. The mechanical misalignment is +20 μm. The optimum image quality is achieved by choosing nozzle 0 as the crossover point. This image is magnified 5 times.*

Figure 8 shows the effect of using the vernier x-alignment (magnified 5 times). The text on top and the text in the middle have been generated with two misaligned systems (leaving a gap in the text at the top and an overlap in the text in the middle), while the text at the bottom has been produced with a system aligned using the vernier X-alignment software feature.

Figure 8. Example of a mechanically misaligned system. -10 µm at the top, and +10 µm in the center and at the bottom. The bottom text corrected by software using the vernier software alignment. This image is magnified 5 times.

The Xaar 5601 GS3 printhead using this feature can correct up to 1 mm of misalignment (±0.5 mm) between printheads, making X axis mechanical alignment tolerance demands easy to achieve and inexpensive.

Solving optical density variations

The pitch difference in the overlap region may produce differences in optical density. This can be corrected by properly increasing and decreasing the drop volume in the higher pitch and lower pitch areas respectively. Such a variation in drop volume can be achieved by nozzle size tuning, but in the case of the Xaar 5601 it can be achieved using per-nozzle voltage adjustment as well.

The Xaar 5601 GS3 printhead incorporates the AcuDrp™ technology which provides the capability of per nozzle (and per sub-drop) voltage adjustment.

In Figures 9, 10 and 11 three real examples of voltage trimming applied to improve the uniformity of optical density across the stitching area are given. In all three images the top part has been printed with a first printhead, while the bottom part has been printed with a second printhead. Both printheads are intentionally misaligned in the Y direction to clearly show the stitching area. The images constitute five bands of flat ink density to show the worstcase of optical density variation.

Figure 9 shows the effect where AcuDrp™ technology is not used, Figure 10 shows 1% density correction, and Figure 11 shows 2% correction using AcuDrp™ technology.

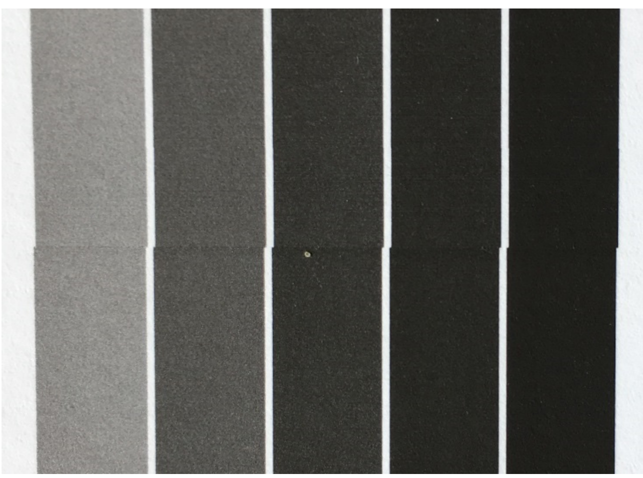

***Figure 9**. Five bands of flat ink density showing a worst case of optical density variation. The top half has been printed with a first printhead and the bottom half has been printed with a second printhead. Both printheads are intentionally misaligned in the process direction to clearly show the stitching area. No correction was applied to print this image.*

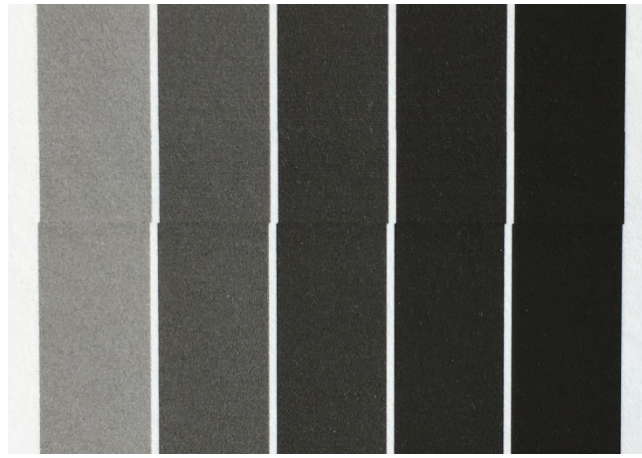

***Figure 10**. Five bands of flat ink density showing a worst case of optical density variation. The top half has been printed with a first printhead and the bottom half has been printed with a second printhead. Both printheads are intentionally misaligned in the process direction to clearly show the stitching area. 1% of ink density correction using AcuDrp™ was applied to print this image.*

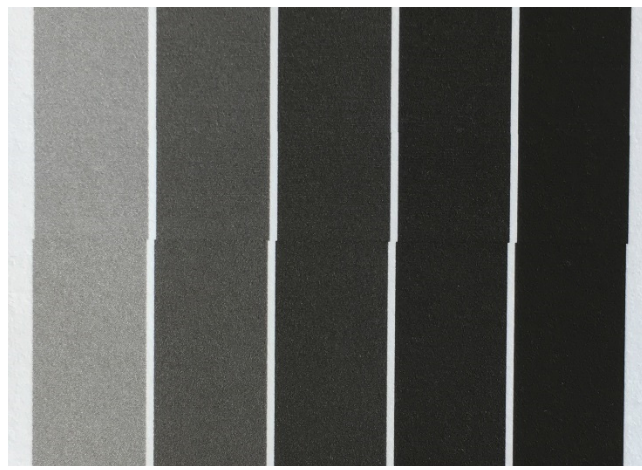

***Figure 11**. Five bands of flat ink density showing a worst case of optical density variation. The top half has been printed with a first printhead and the bottom half has been printed with a second printhead. Both printheads are intentionally misaligned in the process direction to clearly show the stitching area. 2% of ink density correction using AcuDrp™ was applied to print this image.*

Solving process direction errors: image manipulation at pixel level to correct θ_z

Manipulating the image at pixel level is a known technique commonly applied nowadays by many printer manufacturers to correct misalignments. It does not require any specific printhead feature, as it is applied digitally in the data pipeline before printing. Here it is shown, as an example, as a possible implementation to correct θ_z errors.

Assuming all printheads in a single pass (multi-bar, multi-printhead) printer are perfectly aligned between them, printing a line across the media using the cyan printheads, and overprinting another line using the black printheads, the result will be something similar to that shown in Figure 12.

Figure 12. Schematically, two lines (cyan and black) printed one on top of the other in a perfectly aligned printer.

Just the black line can be seen, since it hides the cyan because both lines are perfectly aligned. The two lines can be spaced a given number of pixels apart, and then they would be seen as two distinct lines, as shown in Figure 13.

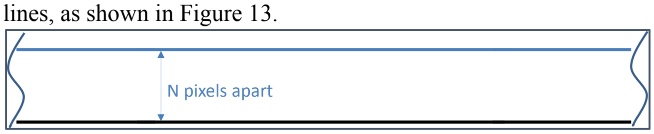

Figure 13. Schematically two lines (cyan and black) printed N pixels apart in a perfectly aligned printer.

If the cyan printhead in the middle of the previous print is replaced by a different printhead and the same pattern is printed again, since the new printhead will be, in general, not well aligned, the new print will look like the image shown in Figure 14.

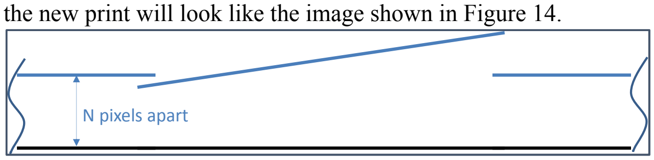

Figure 14. Schematically, two lines (cyan and black) printed N pixels apart in a printer where the cyan printhead printing in the center of the image is not properly aligned.

Now the error can be measured (Figure 14 vs Figure 13) and can be corrected.

The printhead can be divided into, for example, 128 zones as shown in Figure 12 (Other implementations may use a different number of zones for greater or lesser accuracy). The corresponding zones in the image can be moved forwards or backwards an integer number of pixels (each one 21.166 µm in size at 1200 dpi).

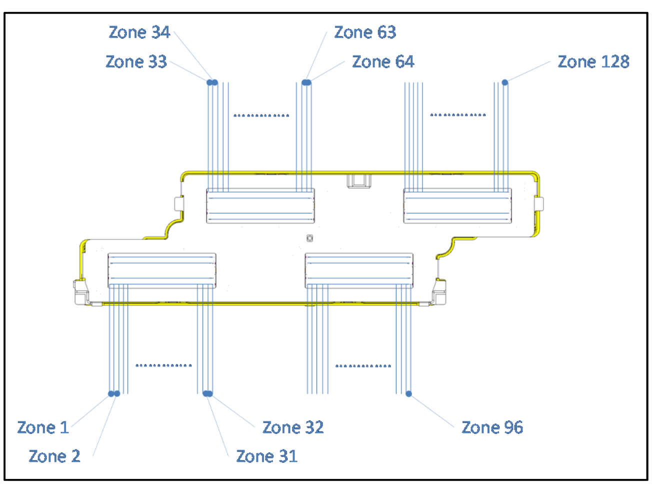

Figure 15. The printhead is divided in 128 zones. The corresponding zones in the image can be moved forward or backwards an integer amount of pixels.

As an example, Figure 16 shows two straight lines (cyan and black), where the middle cyan printhead is misaligned 0.1 mm at each end. Each line is 5 pixels wide (~ 0.1 mm) and the two lines are 200 pixels apart (~ 4 mm).

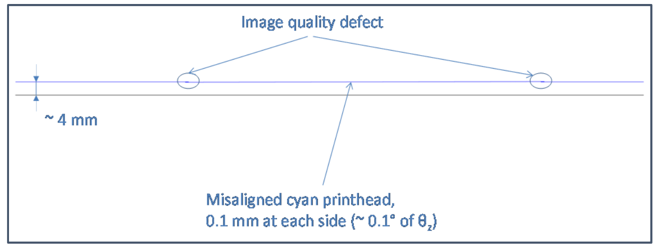

Figure 16. Two straight lines(black and cyan) printed in a printer were the cyan printhead printing in the center of the image is misaligned +0.1 mm at one end and -0.1 mm at the other end.

The center part of the image (the part printed by the misaligned printhead) is split into 128 zones, as shown in Figure 17, and then all pixels in each zone are moved forwards or backwards the optimum amount of pixels.

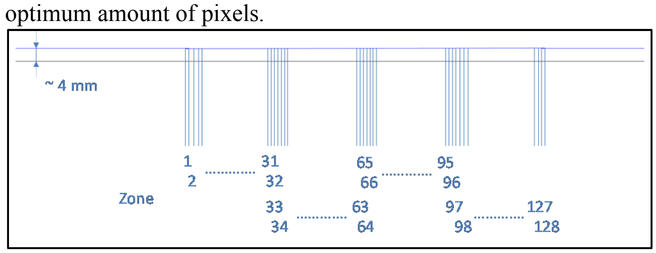

Figure 17. Same image as in Figure 16, but showing schematically the 128 zones in which the center part of the image is split.

For the current example, we have chosen the following correction configuration:

Correction configuration

Zone	Correction	Zone	Correction
1..11	+5	69..80	-1
12..23	+4	81..92	-2
24..35	+3	93..104	-3
36..47	+2	105..116	-4
48..59	+1	117..128	-5
60..68	0		

Table 1. Pixel correction required for each zone in the situation shown in Figure 16.

The result can be seen in Figure 18, where the image quality is clearly better than the original image in Figure 16.

Figure 18.Same image as in Figure 16, but corrected by software manipulating the image at pixel level.

This method can be easily automated by printing an appropriate calibration pattern, scanning it and using the right software to analyze the image.

Figure 19 shows an example of a squared pattern printed by a printer with big misalignment. On the left without corrections, and on the right applying software correction to the image.

Figure 20 shows another example of a text printed by a printer with big misalignment. On top without corrections, and at the bottom applying software correction to the image.

Figure 19 and 20 have been magnified 5 times to show better the effect.

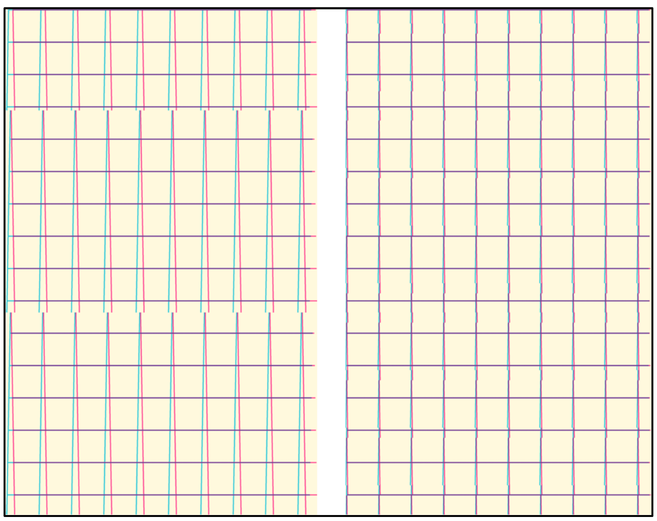

***Figure 19.** Squared pattern printed with a misaligned printer. Not corrected on the left and corrected by software manipulating the image at pixel level on the right. This Image is magnified 5 times.*

***Figure 20**. Text printed with a misaligned printer. Not corrected at the top of the image and corrected by software manipulating the image at pixel level at the bottom. This Image is magnified 5 times.*

Author Biography

Jesus Garcia Maza received his master's degree in Mechanical Engineering at the Universitat Politècnica de Catalunya in Spain in 1991. He is currently working at Xaar in Cambridge (United Kingdom) as Chief Architect on new printheads development, his main responsibility being the development of the Xaar 5601 printhead. Before that he worked at Hewlett Packard in Sant Cugat del Vallès (Spain) as Chief Engineer on the development of latex industrial printers. He is named inventor on over 30 granted patents.