A Novel Approach to Print Head Alignment for Wide Format Printers

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Abstract

For applications using multiple print heads, print head alignment is often achieved through a laborious iterative process of print testing and adjustment.

In order to streamline this process, we have enabled an off-line pre-print alignment method. Relying on quantitative analysis rather than educated guesswork, this procedure enables quick and reliable alignment of the print head in the assembly.

This method uses a precision fixture to hold the print head, while a semi-automated image capture and analysis package provides immediate feedback to the alignment technician as to the direction and magnitude of the necessary alignment changes.

The technique described in this paper has benefits both in the manufacturing environment and in field support.

This paper will discuss the details comprising this novel alignment process including the interaction between the user and the system.

Background

Some printer manufacturers use multiple print heads to increase the number of ink colors for their system to use. Additional print heads are needed for each additional color. Other manufacturers use multiple heads for each color to increase print throughput. To improve throughput, heads are grouped to increase the effective width of a single print swath. Others use multiple print heads to increase effective resolution. To improve resolution, multiple print heads are used for a single color, with adjacent heads shifted precisely to simulate a single print head with a higher number of nozzles.

Print heads in a printer must be properly aligned to each other in order to obtain good print quality. The angle of each head must be correct, and the head to head alignment for each color must be correct, otherwise print quality issues will arise. Misalignment may result in color ghosting from color plane misregistration, banding, or other color matching issues.

Previous Alignment Process

The prior alignment method used by our customer was quite labor intensive and time consuming. First, the set of print heads would be mounted in the printer carriage. Next, a calibration image would be printed and measured manually to see how far off each print head was in its angle and location relative to the other heads. Each of the print heads is equipped with mechanisms that allow the print head to be adjusted for both angle and position along the axis of the nozzles. So once the calibration image was measured, the operator would have to estimate how far to move each adjustment mechanism for each head to achieve improved alignment and then re-print for verification.

This iterative process of printing, measuring, adjusting and verifying would be repeated until the head alignment was deemed to be "close enough".

New Method Overview

The project goal was stated as follows: Create an instrument that enables efficient print head alignment by allowing an engineer to make manual adjustments while providing objective data about alignment quality.

In order to meet this goal, the solution needed to combine sophisticated imaging technology with an intuitive interface.

- ImageXpert needed to capitalize on existing machine vision-based technology for objective and robust image capture and analysis of the print heads, focusing specifically on the attributes that were most important–position and angle relative to an assembly, each measured to a specified tolerance.
- A simple and intuitive graphical feedback had to be provided to the operator since the actual alignment of the print heads to their assemblies was to be performed manually.

The off-line method for print head alignment has been developed and is currently in use. The system is calibrated using a calibration target. Each print head is then placed in a precision fixture and then a machine-vision system takes ongoing images of the print head and provides immediate real-time graphical feedback to the operator as to the direction and magnitude of the necessary alignment changes.

This novel process does not require print testing and takes the guesswork out of the alignment process. When the print head is aligned within tolerances, the graphical feedback indicates this to the operator.

System Description

The system includes a single 2-D CCD camera, a fixture for holding the print head assembly, image analysis software for image analysis and graphical user feedback, and a calibration target (Figure 1).

The system can use images from a single camera with a magnification that allows enough nozzles to be included in the field of view (FOV) to assure sufficient data points for calculating angle and extrapolating nozzle positions outside of the field of view.

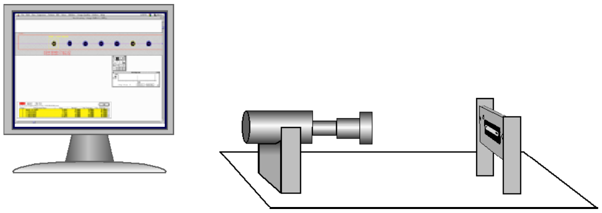

Figure 1. System diagram: single camera takes images of print head in assembly in fixture, the software analyzes the image and provides graphical user feedback during the alignment process

There are a number of factors that were taken into consideration in determining the magnification of the camera. The higher the magnification, the larger each nozzle would appear, providing more pixels for determining an accurate centroid for each individual nozzle. On the other hand, fewer nozzles would mean a less accurate line fit. Another implication of a smaller nozzle count is that there are fewer to spare in case some of them are obscured by debris or scratches. In the end, after repeatability testing over a variety of FOV sizes, the current compromise was reached.

Based on the nozzles included in the image and using reference measurements, the system measures head angle and nozzle position and it measures offset and angular displacement between head and bracket.

In order to address the very real hazard of noisy images, the image analysis software includes an elaborate filtering technique to identify the nozzles in an image that potentially contains scratches and debris.

New Method: Details of Use

Calibration

The first step is to calibrate the system. Using a precision-machined calibration target, the camera is calibrated to accommodate for any distortion and camera misalignment. The calibration process enables the software to report dimensional measurement results in real world units. And it also locates reference features on the fixture and sets nominal values.

The first step in calibration involves acquiring an image of a high-precision calibration target and mathematically comparing the positions of its features in the image, in pixels, to the known physical positions in inches.

This calibration procedure also determines the angle of the X-axis in the real-world coordinate system. This implies that an angle of zero degrees in the image does not necessarily correspond to a measured angle of zero, depending on the mounting angle of the camera.

Eight large dots on the calibration target are used for this step. The actual coordinates of their positions are known and entered into a calibration setup dialog box (figure 2a).

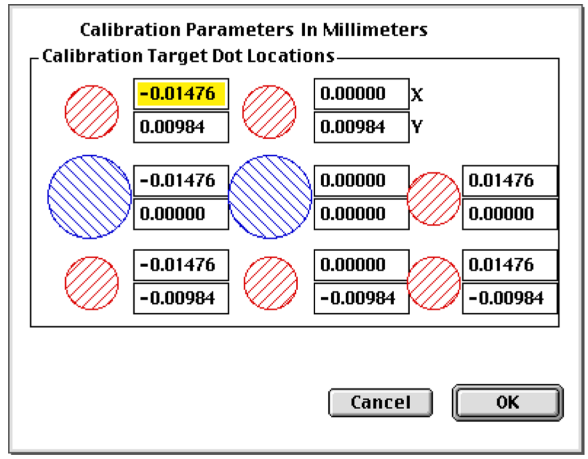

Figure 2a. Calibration set-up dialog box

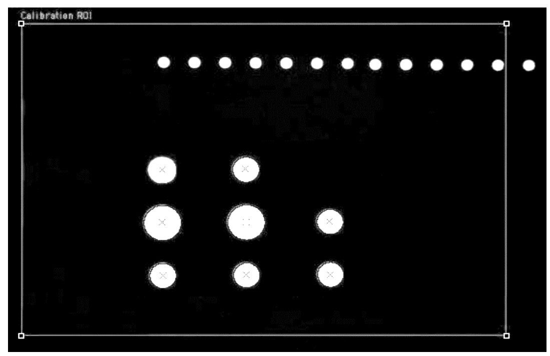

Figure 2b. Calibration target image showing 8 dot pattern

Once the locations are measured using the same camera that will be used in the alignment process, a mapping is created between the image and the object, so that any measured distances and positions can be translated into inches.

The second step in calibration sets the nominal positions of the nozzles. The series of smaller dots on the upper part of the calibration target are used in this step as a surrogate nozzle array. The picture of the “nozzles” on the calibration target represents an ideally aligned print head.

The first dot on the left corresponds to Nozzle 1 of the printhead: there are no dummy “nozzles” on this target. Therefore the first dot on the target corresponds to the Nozzle 1 nominal location on the part, and is subject to slight corrections based on precise measurement of the target. Likewise, the nominal angle, given by the angle of the line through the small dots, is adjusted slightly based on measurements of the specific calibration target being used.

The second step of the calibration process runs a test sequence that contains a processing type called connectivity. Based on characteristics such as brightness and size, the objects that are found are identified as nozzles. From these results, the coordinates of a specific feature on the calibration target are determined.

The preliminary values of the nominal X and Y locations of Nozzle 1 and the nominal angle are based on a priori values from the design and careful fabrication of the calibration target. These values are adjusted in accordance with actual dimensions based on precise measurements of the target.

Alignment

Once the system has been calibrated to set the nominal locations in inches, alignment of the heads can be performed. The results are automatically converted from pixels to inches based on step 1 of the calibration process. The results are compared to nominal values and the graphics indicating pass or fail status are displayed.

A print head is placed in the fixture in the assembly. While the alignment loop is running, the software will provide interactive graphical feedback as to how close the current printhead is to being aligned based on the current measurement values and the tolerances.

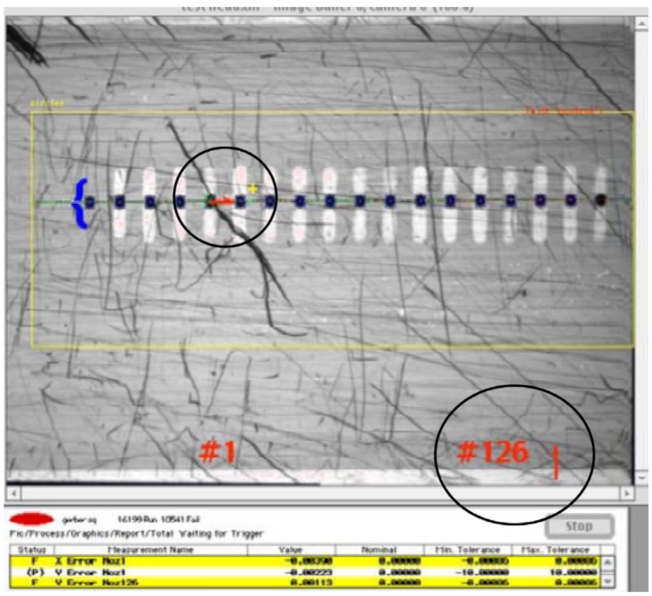

Figure 3. Screen shot from alignment system of actual nozzle array on a print head

The first five nozzles are “dummy” nozzles. The first active nozzle is considered to be nozzle 1.

In figure 3, a red arrow on the left above the label "#1" shows the horizontal distance from the true position of nozzle 1 to the nominal location. A red arrow on the right, next to the label "#126" near the bottom, only provides feedback about the angle. It shows the vertical direction that nozzle 126 (not within this image frame) should be moved to bring the print head angle within tolerance. (Figure 3a shows the arrows more clearly). Both of these arrows turn green when the corresponding values are within tolerance.

A small yellow cross (“+”) (figure 3b) shows the position of the nominal location of nozzle 1 from Step 2 of calibration. Note that this is the nominal location only when the Y error of nozzle 1 is 0, i.e., when the current location is at the same height as the nominal location. If nozzle 1 is above or below that position in the image, the nominal location is adjusted to the left or right.

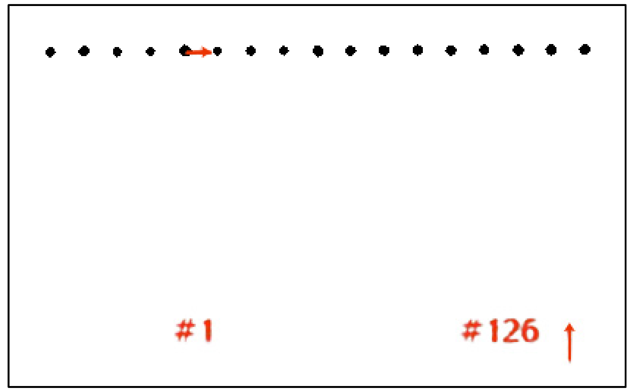

Figure 3a. Abstracted diagram showing nozzles and directional graphics

Figure 3b. Abstracted diagram showing the nominal location of nozzle 1 (6th nozzle from left)

Figure 3c. Abstracted diagram showing bracket indicating start of nozzle array

The blue curly brace to the left of the first dummy nozzle is very important (figure 3c). If there are any nozzles to its left, then all of the measurements are invalid, because that will mean that the wrong nozzle is being assumed to be nozzle 1. This rare situation could occur if, for instance, the actual first dummy nozzle is partially covered by dust or debris, making it unrecognizable to the software but not to the operator.

Please note that all nozzles that are identified by the software as having the correct size, shape, and position (relative to the other nozzles) are marked with an X.

If a scratch or some debris obscures a nozzle so that, for instance, the nozzle no longer appears sufficiently round, the software will not mark it. Additionally, it will not be included in the calculations because it could potentially adversely affect the accuracy of the results.

Other criteria used to filter potential nozzles in the image include overall size, brightness, distance from the best-fit line, and horizontal distances between the candidates. Any of these features could disqualify a candidate from being included in the final line fit. If the number of remaining qualified candidates (nozzles) is less than a preset minimum, the operator is alerted and the alignment cannot proceed until the part is cleaned.

New Method Benefits

Production

Using the machine vision-based system provides more than one advantage. It much easier to align each head, since the operator simply moves the adjustment mechanisms until the vision system indicates that it is within proper alignment. This efficient process is an obvious advantage for the production line assembler.

Field Service

The less obvious benefit is in field service. If a print head needs to be replaced, the old method would necessitate a labor-intensive cycle of print testing and adjustment.

For the printer used in this project, each individual print head is aligned to its own assembly and then the separate assemblies for the individual print heads are installed into the printer carriage using dowel pins that mate with features in the carriage that are very tightly toleranced. This allows each print head to be replaced separately. And since each print head is carefully aligned to the assembly, the alignment (position and angle) of each print head to the next in the printer is guaranteed by the process.

This allows more efficient print head replacement in the field by field service representatives and saves time by avoiding the iterative print testing process.

Conclusion

An off-line pre-print alignment method has been developed for multiple print head systems. Using a single camera, image analysis software and simplified graphical feedback, this new procedure enables quick and reliable alignment of the print head in the assembly. Since there is no longer a need for the time-consuming iterative print-test based head alignment procedure used previously, this allows faster printer set up in production. And in field service, since the vision system is used to pre-align parts, print head replacement in the field is simplified.

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Scott Cole is a Senior Software Specialist at ImageXpert Inc., in Nashua, NH, where he develops application software for both custom and general use. Prior to joining ImageXpert, he was employed at Acuity Imaging as a Software Engineer working primarily in automotive and electronics applications. Before that he worked at Texas Instruments in Austin, TX, as a Software Engineer specializing in robotics, machine vision, and general automation projects. He holds BS and MS degrees in physics.