Technical Disclosure Commons

August 31, 2018

MODELING THE PRINT SCALE IN SCANNED DIAGNOSTIC PLOTS

HP INC

Follow this and additional works at: https://www.tdcommons.org/dpubs_series

Modeling the Print Scale in Scanned Diagnostic Plots

Abstract
To perform visual print quality assessment various print quality metrics need to be measured and analyzed. The measurements made will be used by pen architects, writing system engineers, ink chemists and product quality assessment teams. These measurements are done by an image processing software which performs the print quality measurements on the image of a diagnostic plot. The diagnostic plot image may be acquired from various image acquisition systems, example scanners, area scan camera, line scan camera etc. Diagnostic plots contain predefined patterns designed to measure specific aspects of print quality. In this work, we propose a method to determine the print scaling error introduced during print process and show extended application of the determined affine transformation matrix in correcting the inspection ROI (Region of Interest) placement.

Problem Statement
Determining the scaling introduced during print process is one of the key parameters that is required by writing system engineers. Print scaling can be determined by finding the affine transformation matrix which maps the pixel coordinate relationships between scanned image sample and its respective ideal artwork image. Due to linear distortions like translation, rotation and scaling errors introduced by the scanner, the affine transformation matrix computed cannot be directly used for determining uniform/non-uniform print scaling parameters.

Our Solution
　　Modeling the print scale
　　To extract the print scale parameter along x-axis and y-axis (origin (x, y) = (0, 0) in top-left corner of image), we need to understand how various individual transformation parameters are introduced and how they are constituted in the final affine transformation matrix. This will help us extract print scale parameters from the final affine transformation matrix.
　　In the order of their occurrence, below are the various distortions that are introduced into the scanned sample:
- Uniform or non-uniform scaling introduced during print process (If the image is scaled along both x and y directions by same factor then it's uniform scaling and if the amount of scaling is different along x and y directions then it's non-uniform scaling). For simplicity we will refer to this scaling as print scaling
- Diagnostic print sample may be translated and/or rotated about an arbitrary point when placed on the scan bed (manually or through ADF (Automatic Document Feeder))
- Scanner/image acquisition system introduced uniform or non-uniform scaling (this is a known parameter, determined by calibration of the image acquisition device)

　　Let us represent each of the above distortion using 3x3 affine transformation matrix (M). Let $M_{PrintScale}$ transformation matrix represent the print scaling, $M_{PlotPlacement}$ transformation matrix represent the linear distortion introduced during placement of sample on scan bed and $M_{ScanScale}$ transformation matrix represents the scaling introduced by the scanner. Now, we can represent the final affine transformation matrix M_{Final} as

$$M_{Final} = M_{ScanScale} * M_{PlotPlacement} * M_{PrintScale}$$

$$\begin{bmatrix} \alpha' & 0 & 0 \\ 0 & \beta' & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} \cos\theta & -\sin\theta & cx*(1-\cos\theta)+cy*\sin\theta+Px \\ \sin\theta & \cos\theta & -cx*\sin\theta+cy*(1-\cos\theta)+Py \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} \alpha & 0 & 0 \\ 0 & \beta & 0 \\ 0 & 0 & 1 \end{bmatrix} =$$

Equation $\begin{bmatrix} \alpha'\alpha\cos\theta & -\alpha'\beta\sin\theta & \alpha'(cx*(1-\cos\theta)+cy*\sin\theta+Px) \\ \alpha\beta'\sin\theta & \beta'\beta\cos\theta & \beta'(-cx*\sin\theta+cy*(1-\cos\theta)+Py) \\ 0 & 0 & 1 \end{bmatrix} =$ (1) $--$

Where

α', β' are scanner scaling along x & y axis respectively
α, β are print scaling along x & y axis respectively
cx, cy is the arbitrary point along which the print sample may be rotated
Px, Py is the translation introduced along x and y axis respectively
θ is the angle of rotation

Calculating the M_{Final} from the scanned sample
To determine the affine transformation matrix, we need point pairs that correspond to same image region in both ideal artwork image and scanned image. These point pairs can be either determined by identifying predefined objects in the scanned plot called fiducials or by determining key local feature points in both scanned and ideal image. We can take the ideal and measured locations of three or more (N) fiducial centers to calculate the affine transformation matrix M_{Final}. Let's say A_{ideal} and $A_{measured}$ are two 3xN matrices obtained from the ideal and measured locations of three or more fiducial centers in the sample. The affine transformation matrix M_{Final} is calculated as

$$M_{Final} = (A_{measured} * (A_{ideal})^T) * ((A_{ideal} * (A_{ideal})^T)^{-1}$$

$$\begin{bmatrix} a & b & Tx \\ c & d & Ty \\ 0 & 0 & 1 \end{bmatrix} = \qquad \text{--Equation (2)}$$

Where $A = [P_1^T, P_2^T, ..., P_N^T]$, $P_N^T = [X_N, Y_N, 1]$, a & d are scale factors along x and y axis respectively, b & c are shear factors, Tx & Ty are translation factors.
Using Equation (1) and Equation (2) we have rotation, x print scaling and y print scaling respectively as

$$\theta = \tan^{-1}\left(-\frac{\beta' * b}{\alpha' * d}\right) \qquad \alpha = \frac{a}{\alpha' \cos\theta} = \frac{c}{\beta' \sin\theta} \qquad \beta = \frac{d}{\beta' \cos\theta} = -\frac{b}{\alpha' \sin\theta}$$

The above calculation results can be reported to the suitable reporting tool.

Given the ideal and its corresponding scanned (transformed) image, Affine transformation matrix can also be determined by using other methods like image registration, key points detection and matching etc.

Extended application of M_{Final} to correct the Region of Interest of the objects in a test pattern
In textile printing, the dimensions of Print Quality (PQ) test patterns can be severely distorted. The pattern distortion can affect accuracy of PQ measurement algorithms. In this regard, we should determine the coordinate correction parameters of the scanned sample with respect to ideal artwork which will be accounted by PQ algorithms to locate the objects accurately.
We can obtain the corrected region of interest of the objects in a test pattern using M_{Final}. We multiply the ideal locations of every object in the test pattern with M_{Final} to get the corrected Region of Interest. We convert the ideal locations of each object into a 3*N matrix, let's say A_{ideal} and multiply it with M_{Final} to get the corrected locations, $A_{corrected}$.

$$A_{corrected} = M_{Final} * A_{ideal}$$

Points obtained from the matrix $A_{corrected}$ are the corrected locations of the object on which the PQ algorithms will process and give the correct metrics. The corrected ROI's are shown in Figure 1(b)

Evidence the solution works
We ran our experiment on one of the textile samples. This sample is scaled up in x-axis by 2% and scaled down in y-axis by 3% and is having a clockwise rotation of 2 degrees. Figure 1(a) shows the misalignment of the ROI

(boxes marked in magenta) with the test patterns before the above correction algorithm is applied. Figure 1(b) shows that the ROI is correctly aligned with the test pattern after the above correction algorithm is applied. Calculated results after applying the discussed methods in this paper: Rotation = 2.0009836 degrees, X print scaling factor = 1.02005107 (+2%) and Y print scaling factor = 0.9701101 (-3%)
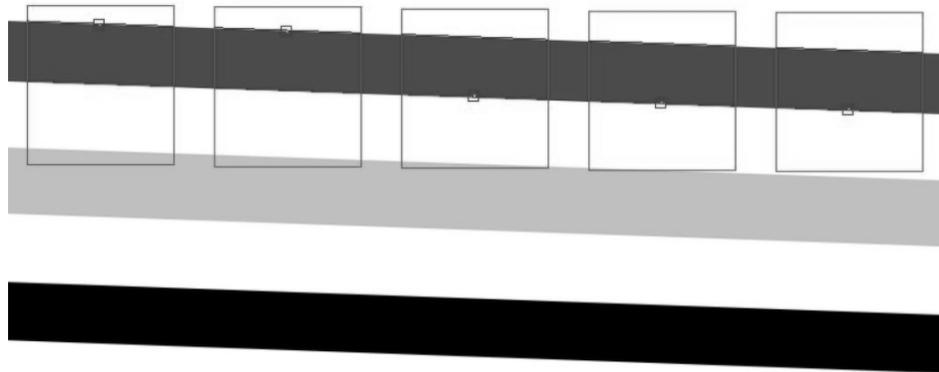

Figure 1(a): Placement of Region of Interest for the objects in a pattern before applying correction.
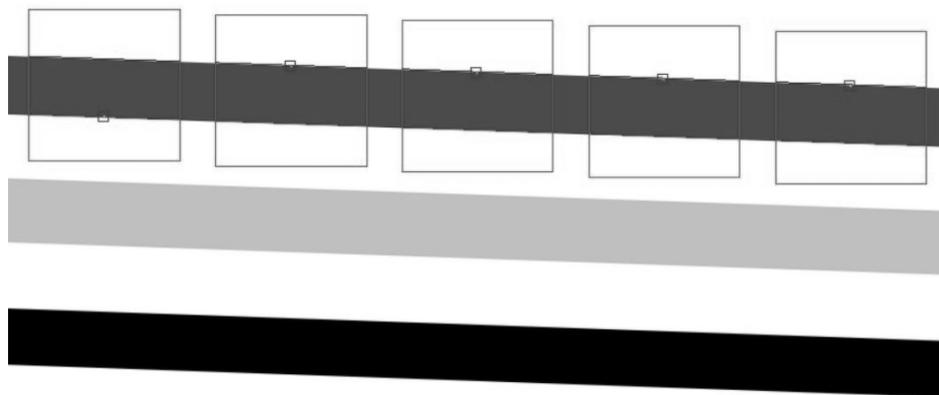

Figure 1(b): Placement of Region of Interest for the objects in a pattern after applying the correction.

Business Impact
This solution enables the robust processing by PQ algorithms in R&D labs and manufacturing sites. This solution reduces the complexity of analyzing the false failures and avoid overhead of rescanning the samples to remove the scan distortions. This enables important use cases of analyzing textile samples which are more prone to having linear distortions due to shrunk or stretched fabrics.

Next steps and Future Work
Our further research includes development of methods to correct non-linear distortions in textile PQ patterns.

Disclosed by Utkarsh Siddu, Elzbieta Bak, Ravi Kumar and Suraj Sarangamath – HP Inc.