Using Slanted Edge Analysis for Color Registration Measurement

Peter D. Burns and Don Williams
Eastman Kodak Company
Rochester, NY USA

Abstract

We describe a digital image processing method to measure translation error between color records, that can be computed from the acquired image. Several steps in the ISO 12233 standard for measurement of resolution for digital cameras are used to locate an edge for each color plane. The method has proven reliable and can be applied to images acquired from both digital cameras and scanners.

Introduction

The recording of detail in a digital color image requires that the color records be detected and stored in register. By this we mean that the signals stored as triplets of red, green, and blue pixel values should indeed correspond to the sampled original image at the same locations. If a digital image is captured with misregistration between the color records, the color image displayed, or printed from these records, can exhibit a loss of sharpness (blur), or color distortion artifacts, particularly at the edges of objects in the scene. In addition, the performance of any subsequent image processing step that relies on the color records being registered, such as color metric transformation, image compression or printing, suffers when misregistration is present.

Measurement of Color Registration by Slanted Edge Gradient

A robust measure of color image translation and rotation error can be computed as a natural step of a well-established procedure for the evaluation digital cameras. The ISO 12233 standard [1-3] for evaluating the spatial frequency response of digital cameras describes the use of a tilted (slanted) edge target feature. The steps included in the procedure are outlined in Fig. (1), similar to Fig. (4) of ISO 12233. The procedure uses a tilted edge to derive an edge derivative (line-spread function), and compute the spatial frequency response.

First, the selected image data in the region of interest (ROI) are transformed to compensate for the camera photometric response (log exposure-digital signal). This is done using three one-dimensional look-up tables, collectively known as the Opto-Electronic Conversion Function (OECF).

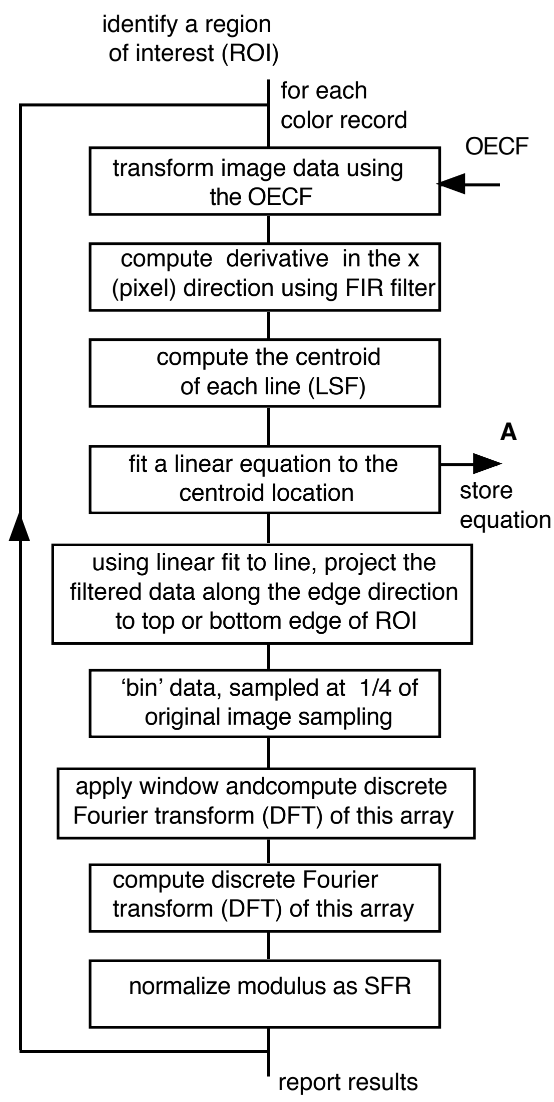

Figure 1: A description of the ISO 12233 Spatial Frequency Response evaluation. Storage of the equation for the edge at step A has been added. The edge is assumed to be oriented in a near-vertical direction.

The edge location and direction (in the form of an linear equation) are estimated. Note that at step **A** an equation is fit to the location (centroid) of the pixel-direction line-spread function (LSF). The image data at all pixels are then projected along the direction of the edge to form a one-dimensional 'super sampled' line-spread function. After application of a smoothing Hamming window, discrete Fourier transform and normalization, the spatial frequency response (SFR) is reported.

An implementation of this method that reports the edge fitting equation for each color record can be used to measure the edge location within the (n lines x m pixels) ROI. Specifically, the equation for the linear fit to the set of line centroid data can be expressed as the inverse of the usual linear equation

$$x = a + b(y - 1) \qquad (1)$$

where x is the x-direction (pixel) location [1-m], y the y-direction line number [1-n], and a, b are constants. The value of a is the location of the edge on the first line of the ROI. Since the ROI is chosen to be identical for each color record, the corresponding values of a and b are expressed in the same coordinates. The above procedure was implemented in software and tested.

Example

A document scanner was used to acquire the digital color image of a monochrome (black and white) edge printed on photographic paper. The image was stored as a 24-bit RGB file. A (128 x 64) pixel area from the image was chosen as the region of interest for the evaluation. Figure (2) shows both a printed version of the ROI, and a perspective plot of digital code values for the green image record. Note that Fig. (2) is oriented so that the first line is on the lower edge of the plot, rather than the upper edge, as is more common for a displayed image.

The LSF array was computed by filtering the image data in the pixel direction, as shown in Fig. (3). To simplify the perspective graphics, every other sample is actually plotted in Figs. (2) and (3). All data was used, however, to compute the set of line centroids, and linear fit. These results are shown in Fig. (4), where the equation was found as

$$x = 27.77 + 0.164(y - 1) \qquad (2)$$

where, as discussed above, x is the edge location and y is the image line number within the ROI. By processing the blue and red image records in the same way, the three edge locations were found. Taking one record as a reference, in our case green, the effective color translation misregistration was found. Adopting the convention of reporting the edge (pixel) location at the center of the region of interest, we simply evaluate Eq. (2) at $y = (n-1)/2$. This is reported in Table 1.

Accuracy

Limited accuracy testing of the method has been performed using synthetically generated edge images, with known color misregistration. For noise-free edges of 70% modulation, the procedure accurately estimated the misregistration to less than 0.01 pixel. For the same edges with signal-to-noise ratios (mean/rms per pixel) of 50:1, the accuracy was reduced to 0.05 pixel.

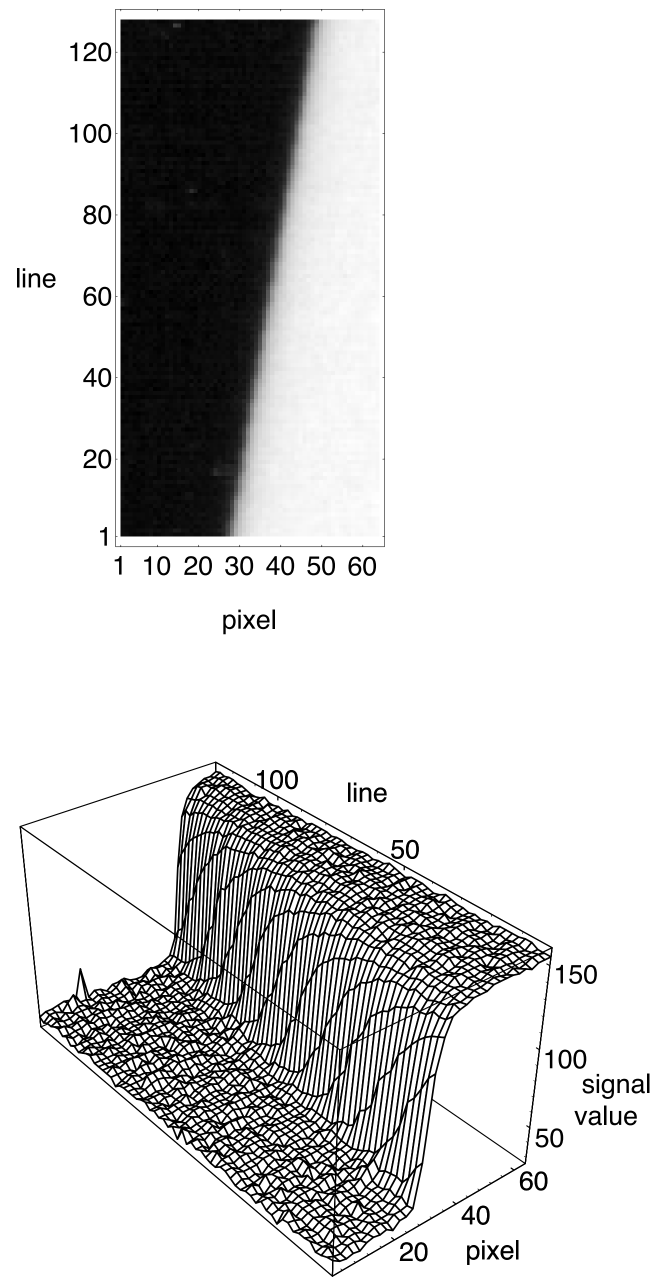

Figure 2: Selected ROI of green image rendered (top) and as a perspective plot (bottom). The signal is encoded on a [0-255] scale.

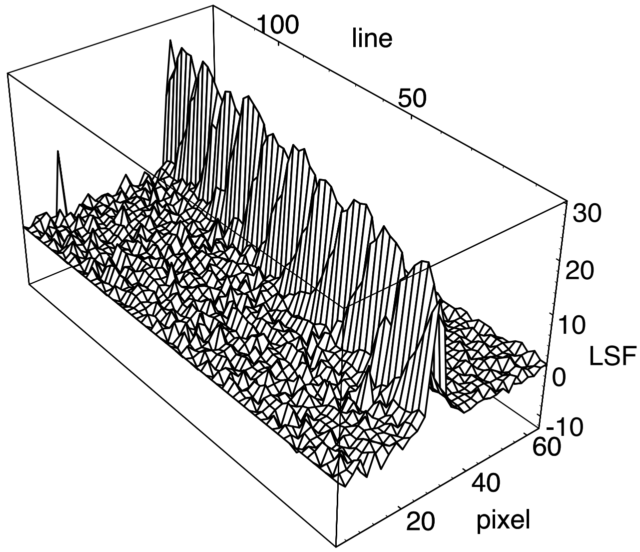

Figure 3: Line-spread function array after one-dimensional FIR filtering.

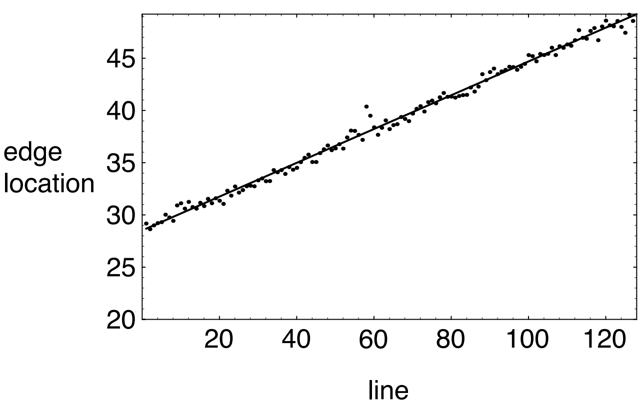

Figure 4: Line-spread function centroid data, with the linear fit

Table 1: Measured edge locations, in units of pixels, for the image from scanner.

	location	shift
red	39.57	0.36
green	39.21	0.00
blue	40.05	0.84

Conclusions

By applying the first few steps of a recommended analysis for digital camera resolution measurement to each of several image color planes, we can measure the effective translation error between colors, at the center of an image or a region of interest. Future related work in this area will include an evaluation of the sensitivity of the method to such factors as image noise, edge angle, and sampling statistics. The current implementation, however, yields sub-pixel accurate for moderate image sizes, and is appropriate for both scanner and digital camera evaluation.

Acknowledgments

Many thanks to Connie Boehmer, Ray Ptucha, and Ralph Short for testing and comments to PB regarding the Matlab implementation of the procedure.

References

1. ISO/TC42 WG18, Photography - Electronic still picture cameras - Resolution measurements, ISO 1998. Available from internet web site: http://www.pima.net/it10a.html
2. T. A. Fischer and J. Holm, 'Electronic still picture camera spatial frequency response measurement,' *Proc. of IS&T 47th Annual Conf./ICPS 1994*, **vol. 2**, pp. 626-630 (1994).
3. D. Williams, 'Benchmarking of the ISO 12233 slanted-edge spatial frequency response plug-in,' *Proc. of Image processing Image Quality , Image Capture, Systems Conf.*, IS&T, pp. 133-136, (1998).