ACTIVE OPTICAL SYSTEMS

AN029

Plate-Type Deformable Mirror Actuator Spacing Analysis

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Abstract

A common deformable mirror (DM) specification is on the accuracy of actuator positioning. This application note describes analysis we performed on the edge-to-edge actuator spacing achieved in our manufacturing process. Over several different DMs, we have measured a standard deviation in the actuator spacing between 45 and 83 microns with an average of 62 microns for actuators on a 6-mm nominal spacing.

Introduction

In some instances, the performance of adaptive optics (AO) systems can be limited by the accuracy of the alignment of the actuators to the sensor. Also, the inter-actuator throw of a DM is limited by the spacing between actuators because the stress increases as the actuator spacing decreases. For these reasons, it is important to have an accurate technique for positioning actuators to achieve optimal AO system performance.

In this application note, we describe analysis performed on images of our plate-type DM actuator grids to determine the variation in as-built actuator spacing from several 42-actuator DMs with nominal 6-mm spacing.

Analysis Methodology

We began by loading the color images into Matlab using the imread() function. We converted the color image to a single gray-scale image by using only the red pixels. (We tried using the average and the other color maps but in these images did not see any significant differences in performance.) We reduced the dimensionality of the problem by analyzing the rows and columns separately. The mean was subtracted from each 1D intensity measurement in the image to make it centered at zero. Figure 1 shows an example 1D intensity profile.

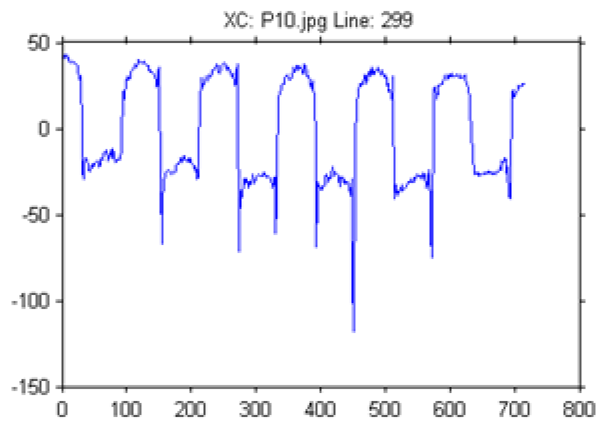

Figure 1 – Example image 1D intensity profile across the 6 actuators

We then found the rising edges of the 1D intensity profile by finding points at which the previous point was below zero and the next point was greater or equal to zero. We then found the separation between the rising edges to determine a measurement of the actuator separation. We rejected any data sets that showed more than 8 or less than 5 rising edges since we had a 6 by 7 actuator pattern. Figure 2 shows an example position and separation analysis from a 1D intensity profile.

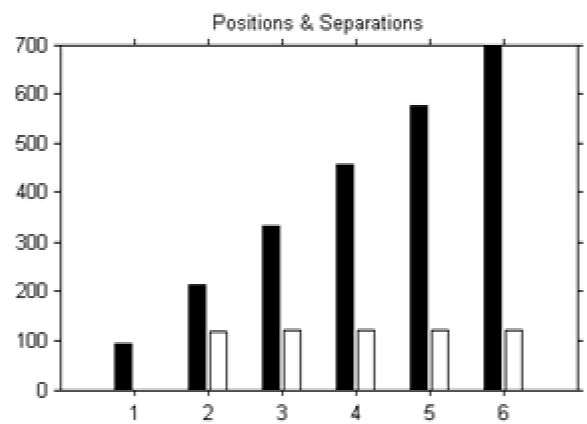

Figure 2 - The rising edge positions in pixels (black) and separations (white)

We compiled all the data from the rows and columns separately. Figure 3 shows the measured separations from all the 1D column profiles in an image. There are clearly some bad measurements from this analysis technique, so we rejected any of the measurements that were outside a 10 pixel window around the peak of the histogram of the measurements. In most of the good data sets, we kept >90% of the measurements. We used the peak of the fast Fourier transform as a relative metric for data quality.

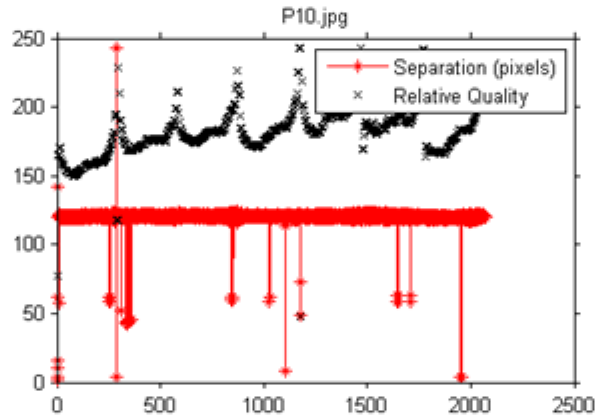

Figure 3 - Collection of the separations extracted from the 1D intensity profiles

We established a histogram of the good data and used the average and standard deviation to fit a Gaussian to the histogram. Figure 4 shows an example histogram of the data from image P2.jpg.

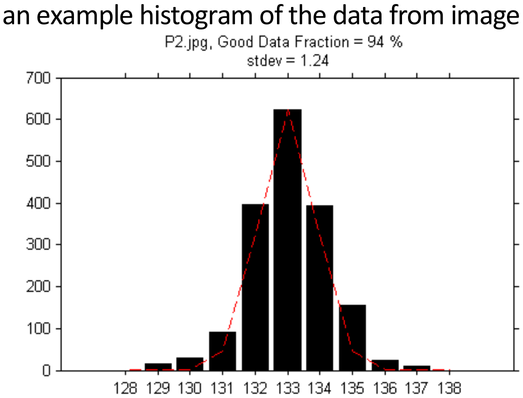

Figure 4 - Histogram of the separation data from an example actuator grid image

We determined the effective pixel size by dividing the nominal separation of 6mm by the average measured separation in pixels. From this we could determine the standard deviation in physical units. The table below shows a summary of the row 1D data from this analysis. We found standard deviation in the separation measurements in this 1D row data from 45 to 83 microns with a mean of 62 microns.

Filename	Good Data Fraction	Center Bin	Standard Deviation (pix)	Standard Deviation (mm)
P1.jpg	93.036212	133.000000	1.158861	0.052279
P10.jpg	98.164251	120.000000	1.038295	0.051915
P11.jpg	96.883988	119.000000	1.122443	0.056594
P12.jpg	80.343214	176.000000	1.684786	0.057436
P13.jpg	85.883749	185.000000	1.729984	0.056108
P14.jpg	86.556687	178.000000	2.027395	0.068339
P15.jpg	60.052219	203.000000	2.259423	0.066781
P16.jpg	90.221402	148.000000	2.008921	0.081443
P17.jpg	91.203704	147.000000	2.030221	0.082866
P2.jpg	93.739881	133.000000	1.238363	0.055866
P3.jpg	96.342477	133.000000	1.039039	0.046874
P4.jpg	95.427604	133.000000	0.997523	0.045001
P5.jpg	94.313725	77.000000	0.784702	0.061146
P6.jpg	93.346008	77.000000	0.927034	0.072236
P7.jpg	87.922705	124.000000	1.413186	0.068380
P8.jpg	96.386631	125.000000	1.344817	0.064551
P9.jpg	97.319778	125.000000	1.288966	0.061870

Comment on Error Sources

We attempted to align the camera to the actuator grids as accurately as possible, but did see some rotational misalignment of the actuators to the camera pixel grid in some of our data. We also saw the effect of defocus and shadows in some of the images. In the future, we would like to perform this analysis again with better lighting and better camera alignment.