Technical Reference Paper

Understanding FARO Laser ScanArm Performance

Executive Summary

The FARO Laser ScanArm® is the first ever seven-axis contact/non-contact measurement device with a fully integrated FARO Laser Line Probe (LLP). Users can accurately measure prismatic features with the Arm's hard probe, then laser-scan sections requiring larger volumes of data, all without adding or removing attachments, untangling cabling, or having to use a separate CMM.

However, there are no official standards or guidelines to assess the performance of such devices. Currently, equipment manufacturers are defining their own evaluation and acceptance criteria. It is important to understand these to make fair assessments and comparisons between the performance of various portable scanning systems.

Overview

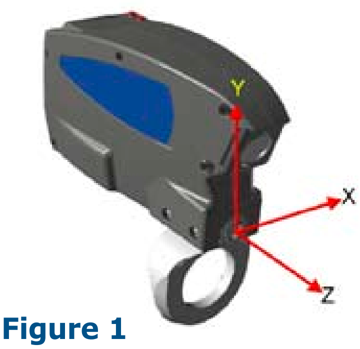


Figure 1

FARO's LLP has a local coordinate system that originates at the laser source, with the Z-axis parallel to the direction of the laser beam (Figure 1).

Accuracy is defined as mean deviation from nominal. Two parameters must meet the acceptance criteria: Average Diameter and Average Z value. Repeatability is defined as the 2 sigma standard deviation of all measurements. Two parameters must meet the acceptance criteria: Diameter Repeatability and Average Z Repeatability.

Average Diameter

During calibration, the LLP is mounted on a linear rail. A calibrated cylinder is placed in the LLP's field of view. The LLP is pointed at the same cylinder as it is moved throughout its entire field of view, from left to right and from far to near covering approximately 85 positions. At each position, the unit captures a cross-section of the cylinder and calculates its diameter. Each measured arc consists of approximately 200 points. The average diameter is then compared to the nominal cylinder value. Figure 2 illustrates diameter deviations at each measured positions. The size of each dot is proportional to the deviation. (Larger dots mean higher error.)

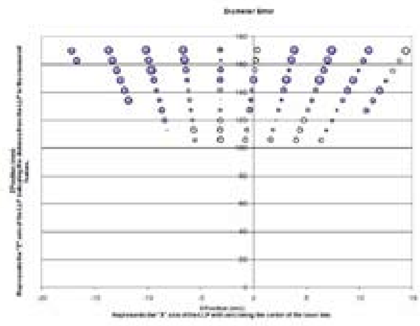


Figure 2

Repeatability is determined by calculating the 2 sigma standard deviation of all the measured diameters.

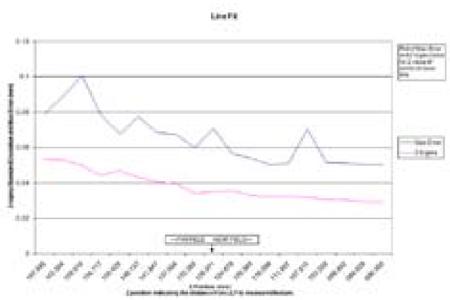


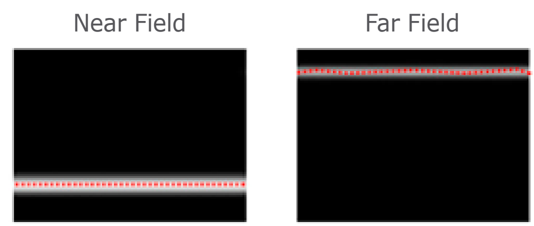
Figure 3

Average Z

During this calibration step, the LLP is mounted on a calibrated linear rail. The LLP is pointed at a flat plane as it is moved from far to near covering 19 positions. Each measurement consists of 640 points on a line straight line. The average deviation from nominal for each point on the laser line is calculated. The nominal is defined by the Z position of the calibration fixture. Figure 3 illustrates the 2 sigma and max errors of line fits at every position.

Repeatability is defined by determining the average z value of all points in the line and calculating the 2 sigma standard deviation in the Z axis.

When analyzing the performance of the LLP over its entire field of view, it becomes evident that data collected in the “Near Field” of the device is more accurate and repeatable than data collected in the “Far Field”. The closer you get to the part the brighter and better defined the laser line appears to the camera. As you pull back it spreads, losing some intensity and definition. This makes it more difficult for the device to determine the true center of the laser stripe, thus resulting in noisier and less accurate measurements (Figure 4).



LLP Camera Image

Figure 4

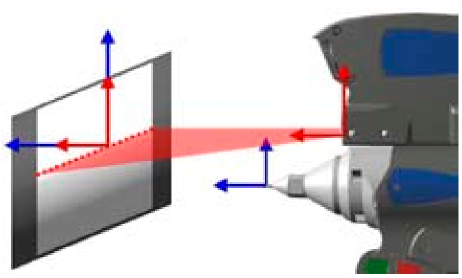


Figure 5

FARO Laser ScanArm Performance

Full system performance is expressed as the compounded uncertainty of the Laser Line Probe and the FaroArm. Actual results are typically better, but are specified in terms of a worst case, combined scenario.

The simplest way to understand full systems performance is to visualize how the error can potentially affect a single data point (Figure 5).

The FaroArm acts as a localizer, tracking the position of the LLP’s coordinate systems in space and then transforming it into Arm coordinates. The single point repeatability specification of the FaroArm represents the ability of the device to produce similar results after measuring the same fixed point in space. The LLP has a repeatability specification that represents the ability to obtain the same Z value for all points in a perfectly flat object based on its unique coordinate system.
If the LLP captures a point at the high end of its performance specification and the FaroArm simultaneously records the position of the LLP at the high end of the arm’s performance specification, the resulting error is taken as the sum of errors from both devices.

Statistically speaking, this is a low probability event, but nevertheless needs to be taken into consideration when evaluating systems performance.

Other Factors Affecting Performance

There are several factors that can have an adverse effect on ScanArm accuracy. Because of the optical nature of the device, things like proximity to scan subject, humidity, temperature, and surface properties like, color, texture and reflectivity can contribute to performance degradation.

Stray reflections can produce double images that introduce noise. The LLP has built-in functionality that attempts to detect and filter them out as they happen. Noisy data and outliers that do make it through are easily corrected in the post processing stage using powerful scan data management software. Some software packages offer additional real time filtering to reduce post processing time.

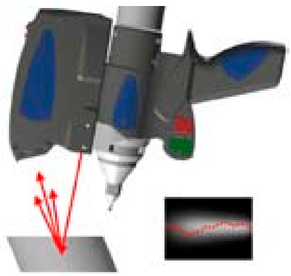


Figure 6

When scanning reflective parts, a certain orientation angle can shine or bounce the laser light directly into the camera's CCD. This produces a "blinding" effect that typically results in very high errors (Figure 6). It is the equivalent of taking a picture with flash directly into your eyes. The camera experiences a similar effect and yields points that are often wrong and should be discarded. FARO's V3 Laser Line Probe has built-in functionality that attempts to reduce the noise caused by reflective surfaces.

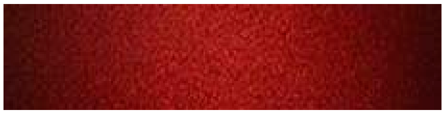


Figure 7

Another major contributor to laser scanner noise is "speckle". The speckle effect is attributed to the interference between the coherent light and the object's surface, resulting in sort of a "freckled" or "spotty" pattern of randomly varying intensities (Figure 7). To determine the position of a point in a laser line, the LLP's camera CCD looks at a stripe of light and converts the pixels with the highest intensity into 3D points. Theoretically, the highest intensity occurs through the center of the laser stripe, but the reality is that the speckling reduces the effectiveness. Optics and software algorithms are used to minimize the effects of speckling.

Conclusion

LLP performance is expressed as an average over the entire field of view. Scanning in Far field allows you to measure more of the part with fewer passes but with reduced accuracy. Scanning in Near Field improves your accuracy but reduces your effective scan width. The middle of the field is the optimum location for best performance and scan coverage. Be conscious of reflective surfaces that can generate double images and generate outliers.