

Technology White Paper

An Introduction to 3D Measurement Technology

Introduction

In today's technical marketplace, there is a constant need for gathering three-dimensional data on parts, products, and environments. Whether it's small machined parts requiring precision diameters, alignment of large equipment or setting up machine tools, or even documenting entire buildings and environments, dimensional measurement data can help companies make more informed decisions and produce better quality products. Collecting these results in 3D provides greater insight into data, allowing companies to have more confidence in the level of accuracy and comprehensiveness of their measurements, all while becoming more efficient.

As technology has evolved, robust, portable 3D measurement tools have been introduced without sacrificing the high level of accuracy and versatility that companies require. Accelerating the digitization of complex parts and environments, 3D measurement technology allows companies to easily verify product quality and collect comprehensive high-resolution data. Replacing physical check fixtures and traditional hand tools such as calipers, plumb bobs, and tape measures, there are several different tools available for the measurement and inspection of parts, products, and environments. The following sections outline various 3D measurement tools, how they work, and their respective applications.

Articulated Arms

Product inspection is a critical part of ensuring quality control; in the past, manufacturers have struggled with bottlenecking issues found in using stationary coordinate measuring machines (CMMs). In order to ensure product quality with this method, items must be removed from the production line and brought to a temperature-controlled room to take measurements. The investment cost for a stationary CMM is also quite substantial.

Other inspection methods include using traditional hand tools, such as micrometers and calipers to take necessary measurements; however, variability between users can skew results and lead to defects later in the process. Additionally, hand tools' use for complex parts is also very limited, and they are unable to work directly with CAD.



The implementation of an accurate and affordable portable metrology solution, such as an articulated arm directly on the production line, can eliminate delays and result in greater efficiencies. Measurement results do not vary between operators, and you have the ability to compare against CAD data.

An articulated arm is a portable CMM that determines and records the location of a probe in 3D space and reports the results through software. In order to calculate the position of the probe tip, the rotational angle of each joint and the length of each segment in the arm must be known. Radial reach when extended typically ranges from 2 feet to 6 feet (4-foot to 12-foot diameter or working volume).

The angle of each rotating joint within the arm is determined using optical rotary encoders. These encoders count rotations incrementally via detection of accurately spaced lines on a glass grating disc. The software converts the counts into angle changes. Arms typically have 6 or 7 axes of rotation, which means the instrument moves throughout a wide range of orientations.

Since these devices are portable, they allow you to take simple measurements in-process or right at the part, eliminating operator and machine downtime and quality control bottlenecks. Companies find that by implementing an articulating arm they are able to increase production efficiency and deliver products more quickly, all while meeting quality standards with automatic, computer-generated reports.

Typical applications for an articulated arm include:

- Dimensional Analysis: Calculate measurements for geometric and GD&T analysis
- CAD-Based Inspection: Measure directly against CAD data to see real-time deviations
- On-Machine Inspection: Inspect parts on the machine tool producing them
- First Article Inspection: Measure individual parts to compare with nominal data
- Alignment: Align parts to assess variation in relative position
- Reverse Engineering: Digitize parts and objects to create full-surfaced CAD models



Articulated Arms with Laser Line Probe Attachments



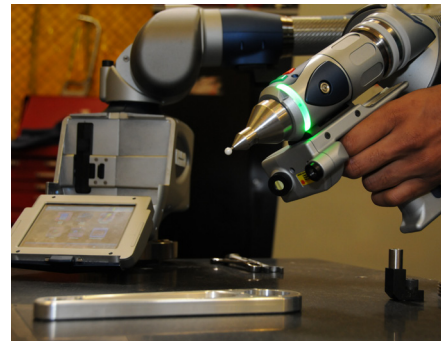
In many cases, the product or part to be inspected is made from soft, deformable materials, making accurate contact measurement extremely difficult. However, the use of laser technology allows for highly accurate measurements to be taken without the need for direct contact.

Attaching a laser line probe directly to an articulated arm allows users to quickly capture dimensions and feature definitions, with or without contact to an object. In order to capture measurement points, a high performance laser projects a beam onto the surface of the object, and a camera looks at the beam to determine the location for each point.

The laser stripe captures data at a scan rate of 45,000 points per second, allowing users to quickly and easily capture large amounts of point cloud data and understand aspects of their parts that they would not otherwise have discovered. A point cloud, also referred to as a scan, contains millions of points in an evenly spaced grid.

Typical applications for an articulated arm with a laser line probe attachment include:

- Non-Contact Inspection: Inspect soft, deformable or complex shapes; perform cloud-to-CAD comparison, rapid prototyping, reverse engineering and 3D modeling
- CAD-to-Part Inspection: Measure directly against CAD data, see real time deviations from nominal
- Reverse Engineering: Digitize a part or object to create a fully-surfaced CAD model



Laser Trackers



Many industrial applications require extremely accurate large-scale measurements. A laser tracker is a portable coordinate measuring machine that allows users to achieve their accuracy goals quickly and easily and replaces tools such as piano wire, plumb bobs, layout machines, theodolites, optical transits, and total stations.

Its large measurement volume allows for the inspection of a wide range of part sizes. When dealing with larger parts and various alignment projects, scrap and downtime can be extremely costly. A laser tracker provides the 3D data needed to get parts right the first time (thus eliminating scrap), and does it quickly enough so that expensive downtime is reduced.

The operation of a laser tracker is easy to understand: It measures two angles and a distance. The tracker sends a laser beam to a retroreflective target held against the object to be measured. Light reflected off the target retraces its path, re-entering the tracker at the same position it left.



Retroreflective targets vary, but the most popular is the spherically mounted retroreflector (SMR). As light re-enters the tracker, two angle encoders measure the elevation and rotational angles while a highly accurate absolute distance meter is used to determine the 3D position of the target.

Typical applications for a laser tracker include:

- Alignment: Real-time feedback of object positioning
- Installation: Lay out / level machine foundation
- Part Inspection: Digital record of actual versus nominal data
- Tool Building: Set up and inspect tools with only one person
- Manufacturing & Assembly Integration: Obtain critical positioning feedback real-time
- Reverse Engineering: Acquire high-accuracy digital scan data



3D Imagers

Implementing automated measurement devices on a rotary stage or robot mounts allow users to perform inspections and verify assemblies quickly and accurately, resulting in significant time and money savings.

A 3D imager is a non-contact measurement device that collects dense surface data on an area of a part. The typical area can range from 100 to 1,000 square millimeters. Due to the point-and-shoot nature of a 3D imager, it is well suited for integration into automated solutions.



3D imagers use structured light projections, which can be a unique pattern of lines or dots. These



projections are viewed by one or more cameras, and through a series of changes in the projections, 3D coordinates can be determined for each pixel in the camera. For example, a 3D imager with a 4 megapixel camera will yield 4 million points per measurement.

3D imagers using structured light techniques can achieve metrology-grade accuracy on critical surfaces. They can also be used to collect data on features, although the accuracy on features will be limited by the resolution of the camera which is what defines the point spacing on the part.

Typical applications for a 3D imager include:

- First Article, In-Process and Final Inspection: Capture a digital record of actual vs. nominal data for parts such as sheet metal parts and assemblies, aircraft skin, tools and dies, castings, and machined parts
- Reverse Engineering: Collect high-accuracy digital scan data for use in as-built documentation, aftermarket product design and virtual assembly
- Rapid Prototyping: Fabricate a 3D-scale model for use in tool modification and iterative product enhancements



Large-Volume Laser Scanners



Capturing measurements of entire environments, such as crime scenes, building facades, or complex piping can be a time-consuming and cumbersome task. Many companies have implemented large-volume laser scanners to produce highly detailed three-dimensional images of complex environments and geometries. Compared to traditional measuring methods such as tape measures, laser range finders, digital cameras, and total stations, a large-volume laser scanner provides a fast, easy, and economical way of capturing millions of 3D data points.

Phase-shift systems emit a laser beam at a known frequency ("light emitted"). Some of this beam is then reflected back to the system ("light returned"). The phase of this "light returned" is then compared to that of the known frequency, and the difference between the two peaks is the "phase shift". Phase shift scanners are considered to be among the most accurate laser scanning devices on the market, with very fast data acquisition and high-resolution scans.



Colorized point cloud data collected using a 3D laser scanner

Typical applications for a large-volume laser scanner include:

- Facility Management: Provide 3D documentation for overall facility management and retrofit projects
- Forensic/Crime Scene Investigation: Capture bullet/blood trajectories, comprehensive evidence collection for crime scene analysis
- Accident Reconstruction: Create 3D models for causation analysis or for use in court



- Architectural/Civil Engineering: Capture as-built documentation for existing buildings, or develop 3D models for use in building information models (BIM)
- Heritage: Document existing conditions for the preservation, restoration and documentation of historic monuments

Summary

Providing robust, versatile tools for manufacturers, measurement service providers, architecture, engineering and construction (AEC) firms, and law enforcement officials among others, 3D measurement technology solutions enable companies to improve workflow efficiencies while achieving the high levels of measurement accuracy required by their various applications. Solutions such as portable CMMs and 3D laser scanners allow users to collect large amounts of data in order to characterize parts in detail; critical surfaces and environments can be measured with a level of confidence and speed not possible with traditional tools.

Portable CMMs such as articulating arms, laser trackers, and 3D imagers allow users to take on-machine measurements, providing consistent and accurate data directly on the shop floor. 3D documentation solutions, including 3D laser scanners, allow users to collect as-is conditions in color for use in litigation, renovations and historic preservation. FARO Technologies is a leading manufacturer of each of these types of solutions. Utilizing cutting-edge three-dimensional technology, FARO is able to provide users with the right product to fit their specific measurement needs.

Want to learn more? Visit www.faro.com or for an interactive overview of the best solutions by industry, visit www.faro.com/city.