Everything You Need to Know about 3D Scanning

This document is intended to be an informative overview of what is currently available in the 3D scanning space for industrial or professional applications. It is not intended to be a promotional piece for any one type of device or for any one manufacturer. However, in the interest of full disclosure, NeoMetrix is a distributor for several different 3D scanner manufacturers, including Creaform, Geomagic, and Steinbichler, and provides 3D scanning and reverse engineering services. With that being said, I will do my best to provide a somewhat non-biased description of each type of device mentioned herein, as well as some helpful hints for selecting the best tool for your application, or selecting the best service provider for your project

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Types of Scanners

There are many different types of scanners currently available from a variety of manufacturers. Home use or hobbyist machines are available for a few hundred dollars, and may even utilize technology that you already possess, such as a iPhone, or a Microsoft Kinect. However these solutions are quite rudimentary, and may not provide the detail or dimensional accuracy required for more advanced applications like reverse engineering or computer aided inspection.

Most scanners operate using the principal of 3D triangulation, which incorporates some type of light source, either laser or structured light, and one or more cameras. The cameras detect data points along contour of the projected light. The typical result of this process is a “cloud of points”.

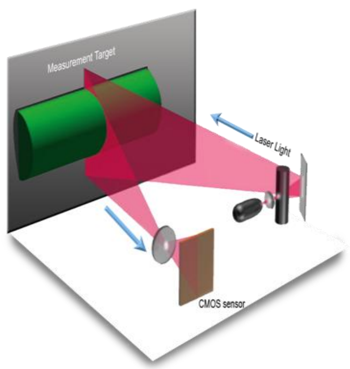

Fig.1: Scanning by Triangulation

There are, of course, many different types of 3D scanners. This document focus on the following:

- Fixed Mounted
- Articulating Arm
- Hand-Held
- Long Range

Fixed Mounted

Fixed mounted, or desktop scanners, scan a fixed area of the subject, based upon the scanner’s field of view. In order to scan a complete object, multiple scans must be captured and subsequently aligned together in order to fully describe the subject.

Fixed mounted scanners are generally integrated with a turntable, which can be calibrated to the scanner. This greatly reduces the amount of manual work required to align all the different scans.

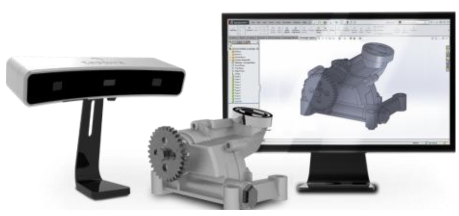

Fig.2: Desktop Fixed Scanner

Another option for aligning multiple scans is the use of optical or photogrammetric targets. 3 or more targets must be common betweens scans in order for the scanner control software to identify which scans match up to each other. The final method of aligning scans requires the manual picking of points common between data sets, or the manual manipulation of the orientation of any one scan in order to match it to adjacent scans. Although effective, the manual method can be somewhat time consuming.

Most scanning projects completed with a fixed based scanner will typically rely on more than one method of data alignment in order to obtain a complete data set that fully describes the object being scanned.

Some systems offer interchangeable lenses, or fields of view, which can expand their flexibility in scanning a wider range of various part sizes.

Fixed mounted scanners, particularly at the high end of the market typically provide the highest degree of accuracy and resolution available, although such systems can be quite costly and require controlled environments and highly trained operators in order to achieve optimal performance.

Articulating Arm Scanners

Introduced in the late 1980's and early 1990's, articulating arms, or portable coordinate measuring machines (CMM's) became very popular as a manufacturing measuring solution, primarily in sheet metal assembly and verification in the automotive and aerospace industries.

Arms can be mounted to a granite table in the inspection lab, or mounted to a portable tripod for data collection on the factory floor, or in a variety of other environments. This portability has made them a popular fixture in the automotive and aerospace industries, particularly for sheet metal measurement and inspection.

The addition of a laser scan head to the end of the arm expanded its capabilities to include non-contact data collection for both reverse engineering and inspection.

Arm based systems can prove cumbersome to use, and do require training and practice in order for the operator to be proficient in their usage. They also require the object being scanned to be fixtured or remain in a fixed location for the duration of the scan. Since all of the data is collected in one continuous session, any relative motion will result in erroneous data being incorporated into the final data set.

They do, however offer the benefit of an integrated hard probe which can be used in conjunction with the scanner in order to provide a higher degree of accuracy on geometric features such as hole locations.

Fig 3: Articulating Arm Scanner

Arms are available in a variety of different lengths, which does affect the accuracy of the system. Shorter arms are more accurate than longer arms.

Hand-Held Scanners

Introduced in the mid 2000's, hand-held scanners represent a major leap forward in 3D scanning technology. By eliminating the need for cumbersome tripods, or mechanical positioning devices, the hand-held systems achieved a whole new level of portability when compared with their more traditional counterparts.

Laser based hand-held systems do require the use of optical targets to be placed on the object being scanned. These targets allow the scanner to establish its position in space relative to the part being scanned. The targets also provide the additional benefit of locking the geometric reference between the part and the scanner, so that any motion between the part and the scanner negated and no error is added to the resultant data set.

Fig 4: Handheld Laser Scanner

Some hand held systems incorporate structured light technology. In some ways they act like a fixed mounted system by scanning a relative large area, but each data patch is dynamically aligned to the adjacent patch automatically. This technique works very well on objects with highly complex geometry, as there are many features available to facilitate alignment. In cases where objects have smooth or simple geometry, the addition of optical targets is required. Systems that do not allow for auto-alignment based upon geometry and alignment based on optical targets will be limited in the types of parts that can be scanned.

Additionally, there are available hand held systems that incorporate a separate optical

tracking system. The optical tracker has the advantage of requiring fewer targets to be

Fig 5: Optical Tracker with Scanner & Probe

placed on the subject, as well as offering improved accuracy over longer distances. Most systems that employ an optical tracker also allow for the use of a hand-held probe for geometric feature measurements. The optical tracker is used to establish a global reference frame between the part being scanned, the scanner and the probe, eliminating errors due to part motion, or vibration in the environment.

Yet another option for hand-held scanners is the availability of photogrammetry. The use of photogrammetry with hand-held scanners significantly improves their accuracy over longer distances by introducing certified scale bars in the optical target array.

Long Range Scanners

Unlike the devices previously discussed, long range scanners require very little operator input during scanning. The operator simply intimates the scan, and the scanner emits a laser beam from its spinning aperture as the entire scanner rotates about its center axis in order to complete a full 360 degree scan of everything in its environment.

Fig 6: Long Range Scanner

Ranges vary from model to model, and from manufacturer to manufacturer, but systems are available that scan up to 600 feet.

These devices are primarily used for surveying type applications on buildings, roads and bridges. However, they can also be employed for "reverse engineering" other larger objects such as boats and aircraft.

Typically not nearly as accurate as desktop, arm based, or hand-held systems, the long range systems do have the advantage of covering enormous amounts of data in a relatively short period of time.

Scanner Performance

The performance of a scanner usually pertains to its accuracy, but there may be other factors as well, such as resolution, repeatability, speed of data collection or ease of use.

One may be willing to sacrifice speed and ease of use for significantly better accuracy. It is important to define your requirements, and the importance of each requirement in order to be able to fully evaluate each technology.

Also, when comparing one system to another, it is important to do an "apples to apples" comparison. Not all manufacturers specify system accuracy in the same way. It may be useful to refer to an international set of standards like the VDI / VDE 2634, which specifies a series of testing procedures using artifacts such as a ball bar.

Fig 7: Ball Bars for Certification

Another method of determining the suitability of a certain device for a certain application is the use of a GR&R test (Gage repeatability and reproducibility). This type of test requires several parts to be scanned several time by different operators. This test not only measures the performance of the device, but also the impact of the operator, and results can be compared to part tolerance as well as part variability.

What Can 3D Scanners Produce?

The raw data from most scanners is a point cloud, which is a collection of X,Y,Z data points usually delivered in some type of text file.

For most applications, a point cloud is fairly useless. Point cloud processing requires specialized software such as Geomagic or Polyworks in order convert the point cloud into a polygon mesh. The mesh can then be further processed to create the "watertight" STL file required for 3D printing.

The uninitiated, however, are usually unaware of the post processing that is required to generate a usable file for 3D printing, or other applications. The degree of post processing required depends directly upon the final application.

Most applications can be distilled down to two primary groups: reverse engineering, or computer aided inspection.

Reverse Engineering

Reverse engineering projects require the final result to be imported into a CAD (Computer Aided Design) system. There are three primary types of models that can be generated from 3D scanned data:

- **Feature Based Solid:** 2D sections are cut through the mesh, and are used to develop sketches. Solid features are created using a combination of traditional modeling techniques, such as loft, extrude, sweep & revolve. IF transferred to the native CAD system is a parametric model, these files are fully editable. However most models are exported as static or "dumb" solids. These are easy to ad to, and subtract from, but not easy to change original shape.

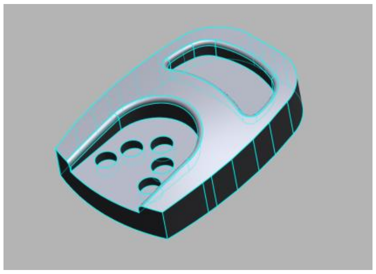

Fig 8: Feature Based Solid Model

- **Rapid Surface Model:** Primarily for organic or sculptural pieces, rapid surfacing requires a network of curves to be developed from the scanned data. Within each "patch" of the network, a NURBS surface is fit such that it is tangent to its neighbor and accurately fits to the underlying scanned data. These models are generally exported to the final CAD system as IGES or STEP or some other neutral format, and are not easily edited in the downstream system.

Fig 9: Rapid Surface Model

- **Hybrid Solid:** This type of model will contain characteristics of both a Feature Based Model as well as a Rapid Surface Model.

Computer Aided Inspection

As opposed to creating a 3D model, computer aided inspection allows the user to overlay the scanned data onto the design CAD model. Deviations can be illustrated as a color map.

Additionally, geometric features can be compared from the CAD to the scan, as well as sectional data.

In general, inspection reports from 3D scanned data produce a more comprehensive view of the condition of the part as compared to other more traditional measurement and inspection techniques.

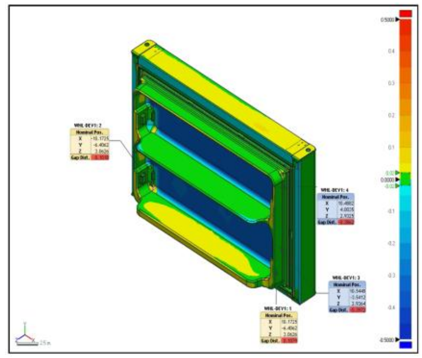

Fig 10: 3D Color Map

Limitations of 3D Scanning

Although extremely useful for a variety of applications, 3D scanning does have its limitations. Since all scanning technologies discussed herein are optical, they all suffer from line of sight issues. So, if you can't see a feature, you can't scan it. Surface finish or reflectivity can also inhibit scanner performance. Some parts may require dusting or coating with a matte white spray in order to facilitate scanning. Finally scanners are not suitable for every type of part geometry. Very geometric or prismatic parts can generally be measured more easily by hand. Scanners are better utilized for those very complex shapes that cannot be measured using traditional methods.

Purchasing a 3D Scanner

When considering the purchase of a 3D scanner, it definitely makes sense to do your homework. Firstly, establish the criteria by which the performance of the device will be measured. Do you need it for reverse engineering, inspection, or both. Also define your budget and your requirements carefully. The use of a decision matrix can be quite helpful in establishing criteria, and rating the importance of each criterion. For example, if both price and accuracy are important, which one is more important. You may find that one device is only marginally more accurate than another, but cost more than twice the price.

An demonstration at your facility, on your parts should also be part of any purchasing decision. Buying complex technology over the phone, based upon a sales pitch will likely lead to buyer's remorse.

Finally, consider the application software that is required to fully address your needs. Demonstration of the complete solution, including scanner and software should be mandatory. Any organization that is unwilling or unable to provide this type of presentation probably lacks the necessary skills to provide follow on support after your take delivery of your system and begin to use it.

Hiring a Scanning Service Bureau

If you only have a few projects per year, it may be difficult to justify the investment in a professional scanning system. Fortunately there are a few competent 3D scanning service bureaus that can assist on a case by case basis. Although an onsite demonstration by a service provider is highly unlikely most reputable firms can provide you with sample data sets, reports, or CAD models in order to demonstrate their ability to meet your needs. Prior to hiring a firm, you may want to ensure that they are using professional grade equipment for your project. With so many DIY scanners now available, you may be getting a very good price on your project, but the final deliverable may be useless.

Conclusion

In summary, there is a lot of information available, so do your research before spending money. Whether you're looking to purchase a system or hire a service provider, ensure that the output or deliverable files will work for your application in your CAD system or with your process. Reputable equipment dealers and service providers are always willing to provide samples at no cost to prove that their product or service will meet your needs.

About the Author

Dan Perreault is the President & Founder of NeoMetrix Technologies, Inc. based in Lake Mary, Florida. NeoMetrix has been in business since 2003, and specializes in 3D scanning for reverse engineering and inspection as well as 3D printing for rapid prototyping. Dan holds a bachelor of science degree in Aeronautical Engineering from Embry-Riddle University, and has over 25 years of professional engineering experience, having worked at ECC International, Lockheed-Martin, FARO Technologies, and Direct Dimensions.