Introduction

Surveying, as defined by the American Congress on Surveying and Mapping (ACSM), is the science and art of making all essential measurements to determine the relative position of points or physical and cultural details above, on, or beneath the surface of the Earth, and to depict them in a usable form, or to establish the position of points or details.

Used across a multitude of engineering applications, surveying takes existing reality and maps it to virtual reality through software or similar mapping systems, to provide documentation of trees, sidewalks, buildings, land contours, topography, break lines, manmade features, and more. Through the years, a number of different measurement methods have been used to collect this data; however, as the need for more accurate measurements has evolved, advanced 3D technology has become available to meet existing needs, and provide comprehensive documentation that was not previously possible through traditional methods.

Surveying Measurement Methodologies

Land surveying is the second oldest profession in the world. Well equipped surveying instruments are the prerequisite in conducting land surveying tasks. Dating back thousands of years, from a time when simple tools such as chains were used to re-establish farm boundaries after the annual floods of the Nile River.[1] Since then, surveyors have significantly improved the various types of technology they use to gather the appropriate measurements for their clients.

Some of the most basic tools for surveyors include the transit or theodolite, which are used to measure horizontal and vertical angles. In the early 1900s, the vernier theodolite was introduced, followed by micrometer theodolite and the digital theodolite in the 1990s.

A typical micrometer theodolite contains as many as 20 prisms or lenses as a part of the optical angle reading system. Although this method can be highly accurate, there is a higher potential for user error when reading angles from the magnifying lens.

The advent of the digital theodolite helped to eliminate these types of errors using an advanced digital encoder system (Absolute or Incremental encoder), a feature that is common in all modern electronic angle measuring instruments. The horizontal and vertical angles are measured by these sensors, and a digital readout is displayed on the screen.

[1] History of Surveying and Measurement, International Federation of Surveyors, http://www.fig.net/hsm/instruments.htm

In order to record a distance measurement along with the angles, one of the earliest methods included the use of surveyor chains. Today, the use of more sophisticated, accurate equipment such as electronic distance meters (EDMs) allow surveyors to measure longer distances by mounting the EDM on top of a digital theodolite, also known as a semi-total station.

Today, one of the most widely used geodetic instruments in conventional surveying technology is the electronic total station, which is a combination of digital theodolite and EDM technologies in a single device and controlled using on-board survey program.

Collecting single point coordinate data (X,Y,Z), the total station uses feature codes to identify each measured point. The data collected by the total station is then brought back to the office, where it is processed and adjusted using software to create surveys or three-dimensional models of the terrain or objects.

Over the years, the total station has seen many improvements to its technology, including reflectorless or prismless technology, which allows the operator to take measurements from the instrument without contacting the object with a target or prism. Although this method is much more accurate and efficient than traditional total stations, the single point measurement collection is a limitation given the time it takes to collect large amounts of data.

Additionally, enhancements such as global positioning systems (GPS) have been introduced to help provide additional measurement data. When GPS was first introduced in the 1980s, it was used to measure long distances between two points, serving as a way to input horizontal and vertical control. As it evolved, GPS for surveying has developed into what is called real-time kinematics, or RTK GPS. Rather than having to take the GPS receivers back into the office to process the data, now the receivers are connected through a radio link, allowing the user to map things in real time with the GPS embedded in the surveying pole.

Although RTK GPS systems help to increase the speed of data collection, there is a positional difference between horizontal and vertical measurement that does not exist with other methods, in that the vertical array is twice the distance of the horizontal. Additionally, horizontal accuracy can be affected by a number of things, including obstructions such as buildings, trees, or fences, resulting in a reduced number of satellites seen by the receiver or reduced strength of satellite geometry.

While the total station is the measuring instrument of choice for many surveyors, advancements in laser scanning technology have led to the adoption of 3D laser scanners as an alternative solution. Operating similarly to reflectorless total stations, 3D laser scanners collect x, y and z coordinates of an entire environment using a single device to generate a high-resolution point cloud. However, 3D laser scanners collect a full field-of-view scan, and do not require location inputs, as the points collected are spatially referenced to the instrument, and not real-world coordinates.[2] As a non-contact, line-of-sight device, the laser scanner captures three-dimensional measurements with accuracies of up to 2mm; using a leapfrogging technique, laser scanning allows surveyors to fully detail a given site or structure. Similar to a total station, collected data is brought back to the office to generate surveys or 3D models as client deliverables.

[2] US Army Corps of Engineers: Control and Topographic Surveying, http://140.194.76.129/publications/eng-manuals/EM_1110-1-1005_sec/EM_1110-1-1005.pdf

3D Laser Scanning for Surveying

Many surveying companies have adopted 3D laser scanning technology to help increase the productivity and detail in their deliverables, improve safety for the field crew, and increase time and manpower savings over traditional methods.

One of the main benefits of implementing laser scanning in surveying applications is the increased level of detail laser scanning is able to provide. Compared to total stations and RTK surveying methods, where measurements must be collected every 50 feet, or at every change in grade or direction, laser scanning allows users to take a full field-of-view scan of an area, capturing a very dense point cloud made up of millions of points which can then be used for mapping land contours and providing a very accurate approximation of what the land looks like.

Surveying in dangerous environments is also a major concern for surveyors; due to the non-intrusive technology of a laser scanner, surveys of plants and industrial facilities are minimally impacted by surveying crews. In hazardous environments, data can be collected from a safe distance, without the need for cumbersome scaffolding or safety harnesses to capture overhead measurements.

Additional benefits of laser scanning include the savings in time and manpower; in many cases, surveys require a two-man crew to gather data with conventional methods. However, with the implementation of a 3D laser scanner, companies are able to capture more comprehensive, detailed data with a single-man crew, reducing project costs and field time. Laser scanning also allows for virtual return trips to a site – eliminating the need for additional site visits to capture a missed measurement.

With several scan setups, laser scanning provides a level of detail not possible with conventional survey methods which are prone to human error and inaccuracies in data collection. Utilizing 3D data collected from a laser scanner, surveyors can provide clients with detailed as-is measurements or 3D models of complex areas or environments for use in civil, architectural, and mining engineering; industrial construction; and piping and ductwork design, installation and retrofit projects.

Applications for the 3D Laser Scanner

Today, surveying affects nearly everything in our daily lives. Surveying is used to establish boundaries of public and private property (cadastre survey), map the ocean floor (hydrographic survey), and provide engineering data for bridge construction, roads, buildings, and land development. Below are some examples of how 3D laser scanners are used in surveying.

Detailed Topographic Surveying

Serving as the basis for engineering, planning and development plans, the data collected in a topographic survey must be comprehensive and accurate. Using 3D laser scanning technology, surveyors are able to capture highly detailed surveys of the land for use as a baseline for future works.

Mobile Mapping

Collecting geospatial data from a mobile vehicle, mobile mapping is a relatively new application for 3D laser scanning in surveying. For projects where hundreds to thousands of miles of roadway or coastline must be measured, mobile mapping provides a non-invasive, efficient way to safely collect data from inside a vehicle in motion.

As-Built Surveys– Bridge and Piping Applications

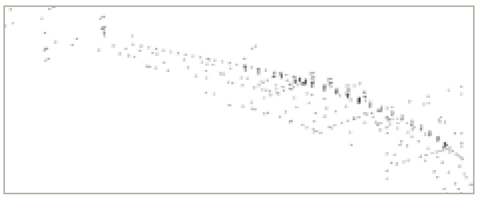

Fig. 1: Data collected using a total station

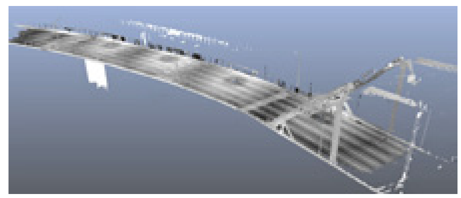

Fig. 2: Same structure, data collected using scanner

As-built documentation for high-traffic structures such as bridges or complex piping within a processing plant can be difficult to collect, given the inherent safety risks of operating equipment on the roadways or in a hazardous environment. However, field survey measurements are necessary to verify accuracy, and to ensure the proper placement and integrity of a structure as it is being constructed, or during retrofit projects.

In order to mitigate risk to surveying crews, many companies have adopted laser scanning as an alternative to traditional methods, given the ability to safely collect data without having to physically stand in potentially hazardous environments, such as a busy intersection or during ongoing production of hazardous materials.[3]

Fig. 3: Capture complex piping structures with a laser scanner

[3] Pilot Study on Improving the Efficiency of Transportation Projects Using Laser Scanning, http://www.ncgia.ucsb.edu/ncrst/research/groundlaser/LaserScan.pdf

As-Built Surveys – Shaft application

The up and down movement of an elevator is highly dependent on the shaft's enclosed space availability.

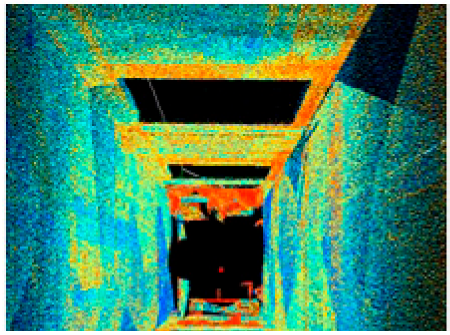

Fig. 4: Top view of the shaft

By replacing conventional surveying methods (e.g. plumb line, total station, etc.) with a 3D laser scanner, engineers are able to quickly and accurately generate as-built documentation, and a comprehensive shaft surface model can be created to review the profile at various levels and ensure a smooth installation process.

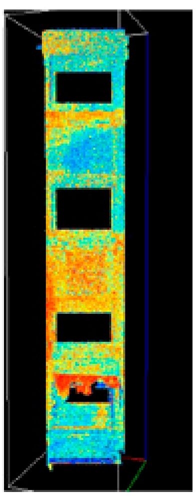

Fig. 5: Elevation of the shaft

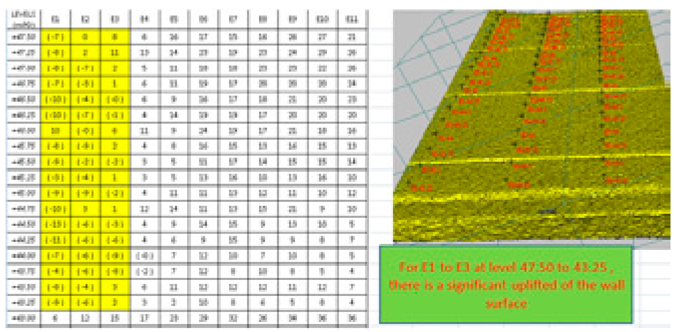

Fig. 6: Data Analysis Report

Volume Extractions

Surveying plays an extremely important role in mining and construction projects that require volume extractions. Utilizing a 3D laser scanner, surveying crews can scan a site before and after an extraction to accurately determine the volume of extracted material.

Fig. 7: Volume calculation using a laser scanner

Tunnel Profiling

In tunnel construction projects, where the shape can be formed using a number of different methods, including the drill and blast method, surveyors are required to perform a profile analysis to view the existing tunnel profile versus the design profile. Using the 3D laser scanning method, surveying crews can use the laser scanner to capture highly detailed point clouds right after the drill and blast process and in-situ concrete lining process. Additionally, sophisticated surface models generated from the point cloud can help engineers to easily identify the over- and under-break areas while easily controlling the entire tunnel project process and schedule.

Fig. 8: Site photo

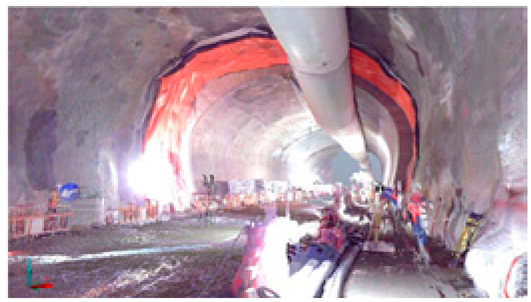

Fig. 9: Point cloud data with RGB values

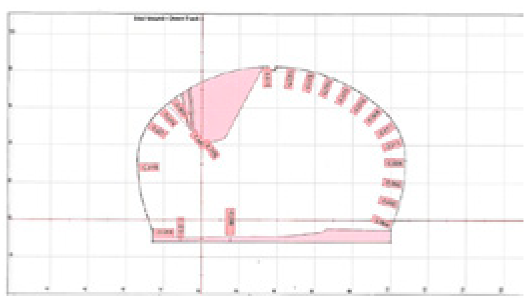

Fig. 10: Cross-section diagram; existing tunnel vs. design profile

Summary

In a typical surveying project, crews can spend weeks collecting hundreds of surveyed points in order to provide the most comprehensive deliverables for their clients. However, improvements in advanced 3D technology have allowed surveyors to escalate their speed of collection while increasing the number of surveyed points gathered, improving the overall efficiency of their workflow.

Providing an alternative solution to traditional measurement methodologies, 3D laser scanners enable surveyors to have a higher degree of confidence in the accuracy of the measurements collected. Utilized in a number of different surveying applications including volume calculations, as-built and topographic surveys, the high-resolution data, along with the speed of collection far exceed the resolution and efficiency of traditional methods.

The FARO Solution

FARO has used their extensive knowledge of real-world applications to develop a revolutionary, easy-to-use, large-volume laser scanner. The FARO Focus3D is a high-speed, non-contact laser scanner, offering the most efficient method for 3D documentation.

The scanner's compact size and weight, combined with advanced sensor features including a compass, height sensor, and dual axis compensator, enable it to provide a comprehensive, robust solution that helps streamline the overall data collection process, from scanning to registration. Delivering photorealistic color scans through an integrated color camera and an intuitive touchscreen display, the FARO Focus3D is a leap in 3D laser scanner innovation and efficiency.

To learn more about the Focus3D, please visit: www.faro.com/focus