Mapping Matters

By Qassim A. Abdullah, Ph.D., PLS, CP**

Your Questions Answered

The layman's perspective on technical theory and practical applications of mapping and GIS

Q1: In Aerial Triangulation, once a least-squares adjustment has been run, the results have been found to be acceptable with no blunders or residuals out of tolerance, there is a decision to be made: Do you overwrite the given ground control values with the adjusted coordinates or do you keep the original coordinates provided by the land surveyor?

Dr. Abdullah: Ground-based 3D laser scanners, which are considered by many experts to be the new generation of survey instruments, have recently become very popular and are increasingly used in providing as-built and modeling data for various applications, such as land surveying, highway surveys, bridge and retaining wall structural surveys, architectural surveys, plant/factory surveys, mining surveys, forensic surveys, reverse engineering, and cultural heritage and archeological studies. In contrast to traditional surveying instruments, which are limited to locating one point at a time, 3D laser scanners measure thousands of points per second, generating very detailed "point cloud" datasets. The point clouds can be processed further to generate very accurate and detailed 3D surface models for use in many commercial CAD packages to extract and model various design parameters and to generate as-built survey reports and analysis.

3D laser scanners of interest for highways and large structural operations are based on the following two different technological principles:

- Time-of-flight (TOF) technology measures the time it takes a laser pulse to hit its target and return to the instrument. Very advanced high-speed electronic devices are used to measure the micro time difference to compute the laser's range, or distance between the instrument and the target. The range data is then combined with extremely precise angular encoder measurements to provide a 3D location of the point from which the laser pulse was reflected. TOF technology is similar to the principle utilized in a surveying "total station" instrument. The difference between the two is the superior point measurement density of the 3D laser scanner, which is capable of measuring more than 50,000 distances per second as compared to the few distances per second that can be measured by a total station device. TOF scanners are commonly used in applications that require significant range measurements (typically 75 to 1000 m), such as highway surveys and other typical state department of transportation (DOT) applications.
- Phase-based technology measures the phase difference between the reflected pulse and the transmitted amplitude modulated continuous wave laser beam. The distance to the target is a function of the phase difference and the wave length of the amplitude modulated signal. Phase-based measurement scanners usually achieve a much higher number of point measurements (point cloud density) than is possible with TOF scanners. However, they are limited in range (typically 25 to 100 m), which makes them best suited for inside factories and enclosed facilities.

In terms of range, both TOF and phase-based scanners are outperformed by total stations that typically can handle measurements a few times greater than that of laser scanners. That said, 3D laser scanners can accurately position objects at a rate of 1,000 times the speed of a total station, which not only reduces survey field time but also results in a more detailed site survey. The enormous survey speed of 3D laser scanners also reduces field crew exposure to all sorts of environmental hazards they are typically subjected to during traditional surveying applications; it also reduces lane closures, decreases the risk of causalities, and increases productivity. For certain applications and projects more than one laser scanner is needed to perform the survey. In these cases, the subject of co-registering data from different scanners plays a greater role in determining the final data accuracy. The process of "registration" refers to combining different point cloud datasets collected using different laser scanners at different locations into a unified coordinate system. These different datasets are joined together in correct relative position and orientation in a common coordinate system. Once joined correctly, georeferencing is performed to complete data processing. Georeferencing is the process of fixing the point clouds dataset(s) to an existing control and coordinate system and datum, such as the local state plane, UTM, and a local site-specified system.

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Many commercial laser scanner manufacturers, including InteliSum, Leica Geosystems, Optech, and Trimble, considered the tighter elevation accuracy requirements needed for the different transportation and highway projects around the world. Such requirement calls for an accuracy of pavement elevation measurements of 8 mm (RMSE) or better from a range of 50 to 80 m. Most scanners achieved an accuracy of 6 mm or better when tested independently by users.

Readers who are interested in more details should refer to an excellent report entitled "Creating Standards and Specifications for the Use of Laser Scanning in Caltrans Projects" recently published by the Advanced Highway Maintenance Construction Technology (AHMCT) Research Center of the University of California, Davis, in cooperation with California Department of Transportation.

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