Autodesk Infrastructure Solutions

Laser Scanning Infrastructure Assets: New Capacities, New Opportunities

Point cloud rendering courtesy of Great Lake Geomatics. NB lanes of I-275, Lower Branch River Rouge, Canton Township, Michigan.

3D laser scanning, or Light Detection and Ranging (LIDAR), is a relatively new technology that is quickly becoming an infrastructure industry standard for collecting data. The accuracy and sheer quantity of the data, and the speed at which it can be gathered, is opening up new possibilities in a sector that has been technologically stagnant for many years.

If you are involved in project work for infrastructure industries—such as transportation, land development, or utilities—that make use of accurate representations of real-world features, it makes sense to learn more about 3D laser scanning: the various types of laser scanning, the kinds of projects that can be taken on, and the types and uses of laser scanning data.

Contents

Over the last decade, LIDAR use has surged in the land surveying and related infrastructure and land development industries, often with profound effects. In fact, as the complexity of the technology has decreased and the capabilities have increased, LIDAR has become the best available solution for more accurately gathering huge amounts of data (millions of points per second, in some applications) and more quickly converting that data into virtual models for use in civil infrastructure software such as AutoCAD® Map 3D, Autodesk® InfraWorks 360™, AutoCAD® Civil 3D®, and Autodesk® Navisworks® Manage software.

Point cloud rendering courtesy of Great Lake Geomatics. NB lanes of I-275, Lower Branch River Rouge, Canton Township, Michigan

Four LIDAR Capture Techniques

For geospatial and infrastructure planning and design purposes, LIDAR capture techniques can be divided into four basic classes, associated with four broad categories of data gathering hardware.

High-Altitude Airborne LIDAR

This typically involves sensors mounted on fixed wing aircraft, flying at altitudes between 1,300 and 8,000 feet (400 and 2,500 meters) above the ground; Global Navigation Satellite Systems (GNSS), inertial measurement units (IMU), and other techniques are used in tandem with the sensors to establish the plane's location. Due to the height, high-altitude LIDAR is less accurate than other laser scanning techniques; horizontal positions can be off by as much as a meter. But high-altitude airborne LIDAR is faster and more accurate when compared to other methods, and is displacing photogrammetry as a method for large-scale topography (like state or county mapping). For example, if a county is developing or refining base GIS layers, one high-altitude airborne LIDAR survey can be mined continually for multiple layers of information, including contours, building locations, vegetation, utilities, roadways, stormwater infrastructure, water features, and more.

Low-Altitude Airborne LIDAR

This is similar to high-altitude airborne LIDAR, except that helicopters are typically used at altitudes between 150 and 2,600 feet (50 and 800 meters). Dedicated GNSS receivers may also be used.

Low-altitude LIDAR's higher point densities make it ideal for large topographic projects that require relatively higher accuracy, such as surveys of transportation corridors. For example, a low-altitude airborne LIDAR survey of, say, 100 miles of freeway corridor could be accurate enough to facilitate repaving plans and the design of new features like curbing, drainage structures, and expanded shoulders. A single afternoon's work for a helicopter pilot and technician, supported by ground crew preparation of control data and monumentation, could potentially supply enough information for years of maintenance and expansion on many miles of roadway. Utility route surveys are also a good example of the revolutionary potential of this technology; low-altitude airborne LIDAR surveying of miles of exposed pipeline could be accurate enough to compare and monitor pipe condition and movement over time, as well as facilitate design and improvement.

Mobile Terrestrial LIDAR Scanning (MTLS)

MTLS mounts two or more scanners on a van or truck, together with GNSS receivers, IMUs, real-time processing, and other equipment. The result is a system that can quickly produce topographic surveys of drivable corridors—collecting information as the vehicle travels highway speeds. The accuracy of such surveys is even more impressive—its routine for MTLS surveys to precisely capture features like potholes and "birdbaths" (shallow, water-holding indentations) that total station crews might not even see, or bother to record. There are only a handful of such units operating in the United States, but that handful is *busy* because the units can be so effective. MTLS also doesn't expose workers to traffic and doesn't require lane closures. For Departments of Transportation and large consulting firms that specialize in roadway design and construction, MTLS is an *extremely* attractive option. MTLS is also being used to drive city streets for façade surveys that are then used in 3D GIS applications, such as AutoCAD Map 3D and InfraWorks 360.

Stationary Terrestrial LIDAR Scanning (STLS)

STLS is the type of laser scanning that probably comes to mind for most surveyors. STLS is useful for conventional topography, exterior and interior as-built, forensic surveying, and monitoring. When combined with scanner-mounted photography, TLS can produce photorealistic virtual models more effectively than any other technology. There are, of course, *many* good examples of STLS use, some of which are quite exotic; for example, in the film *127 Hours*, the actual slot canyon in which Aron Ralston was trapped and was eventually forced to cut off his own hand was scanned by a stationary scanner—and the resulting point cloud and model was used to create a highly realistic set where much of the filming took place. More conventionally, STLS is superb for high-resolution surveys of intricate infrastructure such as bridges and dams; the resulting point clouds can be turned into highly accurate virtual models of the structure and can then be used for 3D model-based design. This type of design is extremely powerful, and enables designers to use automated tools for purposes such as structural analysis, and for clash and interference detection.

Laser Scanning Data

The data collected by laser scanning is generally referred to as a "point cloud." To quote Wikipedia, "A point cloud is a set of vertices in a three-dimensional coordinate system. These vertices are usually defined by X, Y, and Z coordinates…" This definition is correct, as far as it goes, and highlights an interesting feature of point clouds. They are, in terms of coordinates, exactly like the data gathered with conventional survey techniques, such as total station topography. After all, points with XYZ coordinates are the very foundation of modern survey and engineering practice. But the laser scanners used in survey work can do more than gather coordinates; depending on the sensors deployed, scanning data can include data such as RGB values and reflectivity, and can be combined with video data to create photorealistic images.

So point clouds are qualitatively different than conventional survey data, and they are substantially different quantitatively, as well. In a conventional topographic survey, for example, a few thousand points may be gathered, whereas data sets (point clouds) resulting from laser scanning may easily exceed a *billion* points.

This amount of data collected creates entirely new challenges for designers, and the rapid acceptance of laser scanning as a commercial solution had as much to do with processing and software refinements as it did with technological breakthroughs that improved actual laser scanners. Functionality found in Autodesk® Infrastructure Design Suite Premium and Ultimate can work with point cloud data in various ways. For example, users can create more accurate digital elevation models using the data. Due to the fact that point cloud data sets are very large, commonly containing millions, and occasionally billions, of points, an indexed point cloud data store is created so the software can more effectively work with the data. Users can filter the indexed point cloud data by classification, elevation, intensity, or location, to work only with the data that represent the desired existing features.

Point clouds are occasionally used in a raw state, for monitoring applications, for example, but are more often converted to various types of 3D models for manipulation by conventional infrastructure planning and design solutions such as AutoCAD Civil 3D or Autodesk Navisworks software products. Conversion usually involves surface modeling techniques such as non-uniform rational basis spline (NURBS) or triangulated irregular network (TIN). These are not new techniques; however, when applied to dense point clouds the resulting surfaces are so detailed and more accurate, compared to the results of previous techniques that they amount to a new design deliverable.

When combined with imagery from scanner-mounted cameras, point clouds can be used to create near-photorealistic images; that is, in addition to being more spatially accurate, the resulting models will also be more visually accurate.

Point clouds are also unique, compared to previous deliverables like topographic maps and as-built measurements, in their ability to deliver *ongoing value.* Most design tasks are unlikely to exhaust the utility of the scanning data gathered, but because it is easy and fast to gather large amounts of data during fieldwork, laser scanning somewhat upends the conventional survey wisdom that calls for minimization of expensive field time. For example, suppose a survey firm is asked to survey a roadway corridor where safety improvements are being proposed. While in the field, it may make sense to spend a few more hours scanning a wider swath of land, beyond the limits of the current survey. That way, if an alternative design option is considered, the original survey can provide all the additional data needed…*without additional fieldwork*. This is called the “remining” of scanned data, and is one of the more exciting possibilities opened up by this new technology. Since subsequent office work is limited only to the area of interest, the return on investment (ROI) from collecting the additional information is high.

Return on Investment

It has been difficult, so far, to assign precise ROI values to laser scanning. This is for two main reasons: the data sets and deliverables derived from laser scanning are so different from traditional deliverables that they are difficult to compare; and because laser scanning capacities are so much greater than previous solutions they are often used on projects where conventional techniques might not have been attempted.

One obvious source of value is that the technology uses the same manpower to deliver far more value in much less time, but another source of value is safety. Since scanners can do their work remotely, they have been used to perform surveys of dangerous areas, such as unstable rock faces, quarries, and toxic mine tailings. This value, though hard to quantify, is real and may well result in lower insurance rates and fewer injuries at firms that displace at least some conventional techniques with laser scanning.

One source of quantified ROI is the California Department of Transportation (Caltrans), which published a cost-benefit analysis (*Mobile Scanning—Cost and Benefit Analysis Caltrans District 4 Doyle Drive Project San Francisco, CA, December 2009*) in connection with the department’s first major use of mobile terrestrial scanning, the Doyle Drive Project in San Francisco. This was a high-accuracy survey of about 20 miles of high-traffic, four-lane freeway. Even when accounting for mobilization costs of the mobile scanning equipment (the work was subcontracted to an out-of-state provider) the department realized a direct savings of $65,800. When costs of freeway shutdown (to the public) are factored in, the report estimates a total savings of $167,800. Neither figure accounts for additional savings due to remining of the scanned data, additional value due to data used in visualizations, or increased crew safety due to minimization of traffic exposure.

A Golden Age of Infrastructure

The extraordinary new capacities of laser scanning have led to its rapid refinement by manufacturers and widespread adoption by design consultancies. To keep up, makers of design software have rapidly integrated new capacities into software suites in order to make greater use of the rich data sets that are now available. Autodesk® Infrastructure Design Suite, for example, maximizes point cloud value with several capabilities, including:

- More rapid visualization of site conditions.
- Faster conversion of point clouds to data suitable for design environment.
- Automated extraction of linear data like breaklines and top of curb; of planar features like water surfaces and roadways; and of site features like manholes and hydrants.
- Virtual measurement of as-built data such as bridge clearances.
- Better detection of clash and interference issues.

When data gathering advances such as laser scanning are combined with technological advances in design, like the model-based design techniques facilitated by AutoCAD Civil 3D, and new construction solution breakthroughs like automated machine guidance, truly amazing productivity gains are possible. And this is a very good thing because we live in a world that puts great stress on infrastructure. Existing infrastructure in developed countries is crumbling and needs rehabilitation, and there is a critical need for new sustainable infrastructure in *all* countries.

Huge gains in technology and productivity, combined with great need, suggest an emerging golden age of infrastructure that will remake much of the built environment. The challenges are also great, of course, and there are difficulties ahead. But these are exciting times for infrastructure professionals, and their ability to make skillful use of new tools may well save the world.