Laser Scanning from the Ground Up

By Robert A. Fowler, OLS, OLIP

Combination of four scans

Airborne laser scanning survey systems have been around for many years, although it seems it's only in the last few years they have really become accepted as a legitimate and accurate method of mapping terrain and features quickly and economically. Now a similar technology is available for ground-based surveys, as a stand-alone system or in conjunction with other survey technologies: ground based laser scanners.

While there is considerable variation in the capabilities and functionality of various systems commercially available, all of the systems essentially work in the same way. They send out a laser beam and measure the time it takes to travel to an object and back. The time is then divided by two and multiplied by the speed of light to obtain the distance to the object. The scanning unit includes the means to provide the angle between each successive pulse in relationship to the unit so the direction of the beam is positioned in space. Because angles and distances are known to every point from which the system gets a return, it is then simple geometry to use these data to calculate the distances between various objects scanned.

Optech Inc., one of the major airborne lidar systems manufacturers in the world, produces the ILRIS-3D model. Their first unit was sold in 2001 to Northway Photomap, a mapping company located a few miles from Optech's headquarters in Toronto.

The system itself is portable and sits inside a box approximately 1ft x 1ft x 8 inches and mounts onto a standard surveying tripod. (It's preferable that the unit is roughly level, but the unit does not have to be absolutely perpendicular to the ground.) Its rechargeable battery will operate for up to five hours. The Optech laser operates in the infrared end of the electromagnetic spectrum, so there is no visible light but unlike the airborne systems, which are dangerous at close range, the beam used by the ILRIS is completely eye safe. The unit specifications say it will work from three metres to more than 500 metres from the scene or object to be surveyed, but Northway Photomap's general manager, Paul Francis, says that under the right conditions it can be used to scan objects up to 800 or more metres away. However, the scan angle or angle of view is 40 degrees in both horizontal and vertical directions (+/- 20° from nadir), so at longer distances, the effective scene coverage is large, and individual point spacing becomes further apart. The laser beam itself is about 12 millimetres wide at source and distends to 20 mm at fifty metres and 29 mm at one hundred metres.

Optech Image

The unit operates at a rate just under 2,000 hertz; that is it sends out and receives a pulse up to 2000 times per second. The unit directs the scan by focusing the laser beam onto two finely calibrated mirrors, one of which directs the beam along a horizontal path and the second, which shifts the beam vertically for the next horizontal scan. The Optech system also collects the intensity value of the returned signal. This can vary from a return signal of only 4% from piles of black coal, effective up to 350 metres away, to a 20% reflective signal from light colored concrete up to 800 metres away.

The unit includes a colour digital camera, which allows the operator to see the area being scanned and make adjustments as necessary. The area of scan can be selected so that, for example, if there is a large area of sky in the scene, the scanning height can be set so that time is not wasted trying to collect non existent or irrelevant data.

The typical scan takes between ten and twenty minutes with 120,000 points being collected per minute, all to 10mm accuracy. The processed data form a three dimensional view of the scene, and the digital color image is also recorded. As mentioned earlier, because all of the data are recorded in a three dimensional relationship to the system, the distance between objects in the scene can also be measured using simple geometry in the processing software.

What happens if someone walks in front of the scanner or a vehicle drives by? Not very much! You lose a small segment of the scan, maybe a line or two - unless the person stands in front of the scanner for several seconds. A vehicle zipping by may interrupt the scan for a fraction of a second meaning a few hundred points out of close to 2.5 million may be missing. The system can be paused if a vehicle parks in front of the beam.

The next question is how to tie these 3D data to the real world? The scanner merely collects all of the data in relation to itself. "That's simple," says Paul. "If you need to do this (and not every client needs a coordinate reference frame), you survey up to four positions that can be targeted in the scene and give them GPS (or total station) coordinates with position and elevation. The scanner can be set up anywhere suitable. The processing software allows you to select individual targets on the scan and insert real coordinate values for the targets.

Grave lidar

Reprocessing the data to real map projection coordinates is usually done in a matter of minutes."

You can also tie adjacent scans together very quickly if the scene or area is too large to fit into one scan. And if it is a really complex scene, views from several angles can be combined to provide a fully rounded three dimensional product. In either of these cases, however, there must be overlap between scans and at least three points in each scene, which can be identified in the overlap of adjacent scans.

However, it should be noted that the system cannot penetrate or see through solid objects, so a rack of pipes in an industrial complex will only show the pipes as seen from the location of the system. The unit cannot see a second pipe if it is hidden behind the first. Nevertheless, a 3D scan of a segment of an industrial plant can be surveyed in minutes compared to a total station survey which could take hours or days to complete. (On the other hand, at a test scan I observed earlier this year, the system was able to pick out the distance to the back wall of an office through a window!)

The processing software is simple, easy and quick to use. Once any scans are tied together, it is easy to rotate the data in space and view from any angle.

What further impressed me, in an unrehearsed demonstration, was the quality of the intensity data capture. In various different scans an amazing amount of detail was readable from the intensity readings.

Crime scene photo / lidar

Sometimes you can read a street name from a nameplate attached to a pole. Different materials with different reflectivity can really stand out. Inspection scans on towers and poles show a remarkable amount of detail, and sags on power lines can be calculated accurately.

But what sort of time is really involved? Paul provided the following times for a project completed at Toronto's Pearson International Airport where depressions in the tarmac were causing problems. Four scans were made, each of 14 minutes duration. The total field time was four hours including getting everything through security and set up. The client wanted the data georeferenced, so four

Forensic dig - a shallow grave

... views from several angles can be combined to provide a fully rounded three dimensional product.

hours were also expended completing a GPS survey. Processing of the data took 3 hours and then final georeferencing the data a further two hours. Contours and final data products for the client took six hours. The total time expended on the project was 19 hours. Trying to do the same thing with a total station would have taken longer and would have resulted in much less data.

What else can you use ground-based lidar for? Well there are numerous applications, which can be pretty well all summed up as collecting information, especially where it is either dangerous or difficult to measure things directly, or where to do so would take so much time it would be considered uneconomic.

"As built" plans can be constructed of structures in a minimal time, or in cases such as a busy highway where it would be too dangerous to survey by conventional methods. Inventory of stock piles of materials can be surveyed economically, as can quarry faces and mining or landfill applications with a resulting detail that would be difficult to meet by traditional ground survey methods.

"There is also a small market, which is much more prevalent in Europe but may catch on in North America," Paul says, "for cultural and historical surveys. Building facades can be captured quickly in 3 dimensions." He also mentions reverse engineering. For instance an industrial mold can be surveyed and the data kept in a digital file without the necessity of keeping the mold. If it's ever needed again, the data are there to reconstruct the form. Complex industrial plants can be surveyed relatively quickly.

Northway Photomap has also surveyed crime scenes, accidents and recorded data at an archeological dig for forensic purposes.

Optech, themselves, were invited to rush a unit to the New York World Trade Center after 2001's disastrous terrorist attack and supplied measurable data, which analysts used to determine the real situation and safety aspects.

What does an instrument like this cost? The Optech unit sells for about US$150,000, but Optech isn't the only manufacturer to produce ground based laser scanning survey instruments. There are several on the market. These vary according to the effective distance they can be used for, how eye safe they are, their accuracy and so on. Like everything else, depending on the conditions in which you expect to do most of your work, your budget and the specifications you need to meet, you can choose between a number of solutions: you have to do your homework first! Or if this is a technology like airborne laser scanning or aerial photography, which you would use only for specific projects, subcontracting a service provider like Northway Photomap is the way to go.

Paul Francis says he "took a leap of faith" when he bought the unit, and he found that he had to put in some sales effort to develop his market, but is now finding increasing uses for his unit. The high level of detail for and the speed of the data capture shows that, for many applications, this can be a very cost effective way of completing a detailed ground survey economically, or complementing an airborne laser survey with additional information at specific locations.

A different version of this article was first published in Earth Observation Magazine, October 2002. You can get more information about the Optech ILRIS from the Optech web site at www.optech.on.ca and you can contact Paul Francis, OLS, at pfrancis@photomapltd.com Author Robert Fowler is vice president sales and marketing for Lasermap Image Plus/GPR, an airborne lidar service provider, and can be reached at bobf@lasermap.com

Calendar of Events

*****

February 19th to 21st, 2003

AOLS Annual General Meeting (Sheraton Fallsview Hotel)
Niagara Falls, Ontario
www.aols.org

March 2nd to 5th, 2003

GITA Conference 26
San Antonio, Texas
www.gita.org

March 12th to 14th, 2003

ACLS Annual Meeting
Saskatoon, Saskatchewan
www.acls-aatc.ca

March 16th to 19th, 2003

GEOTech Event
Vancouver, B.C.
www.GeoPlace.com/gt

March 29th to April 2nd, 2003

American Congress on Surveying and Mapping
Phoenix, Arizona
www.acsm.net

April 26th & 27th, 2003

CCLS Annual Meeting
Calgary, Alberta
www.ccls-ccag.ca

May 29th, 2003

Statutes Exam and Professional Oral Exam
venue to be confirmed

May 30th, 2003

Professional Written Exam
venue to be confirmed