Overview of Mobile LiDAR for Transportation Applications

PAG Transportation Systems Subcommittee / RTA Safety Working Group

November 15th, 2013
Figure 5. Comparison of airborne and mobile LIDAR systems.

**Airborne LIDAR**
- Direct view of pavement & building tops
- Poor (oblique) view of vertical faces
- Faster coverage
- Larger footprint
- Laser travels much farther
- Not limited to area visible from roadway
- Lower point density (1-60 points/m²)

**Mobile LIDAR**
- Good view of pavement
- Direct view of vertical faces
- Cannot capture building tops
- Slower coverage
- Smaller footprint
- Closer to ground objects
- Limited to objects close and visible from the roadway
- Higher point density (100’s points/m²) but more variable
TRANSEND
May, 2010

A magazine for employees, retirees and stakeholders of the Arizona Department of Transportation

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GOING 3-D
Bulked-up photolog van takes data to a new level, p. 3

3D point cloud of an underpass in Phoenix
On the road: Photologgers capture more than 8 terabytes of images and data from state highways

by John Tucker, Editor

Every spring, Robert Bush and Tim O’Connor hit the road in a nearly $750,000 van to take photographs of Arizona.

It might sound like a dream trip, but the transportation photolog specialists are on the job, using high-tech cameras, lasers, and GPS technology to create a comprehensive record of the state highway system.

From mid-March to mid-September, Bush and O’Connor typically spend their work weeks collecting images and other data on an average of 250 to 275 miles of Arizona highways each day. One drives while the other mans a workstation in the middle of the van, monitoring the cameras and other equipment through two powerful PCs. The two men sometimes trade off on the duties.

ADOT began photologging the state system in 1970 with a 16mm color-film camera mounted to the dashboard of a van. The new photolog van, which made its maiden voyage in March 2009, makes all its forerunners look like horse-drawn buggies.

It’s a specially designed 2008 Ford E350 van equipped with two sophisticated high-definition cameras and a host of other high-tech equipment mounted on top of or stored inside the van. The two cameras take HD photographs every 10 meters as the van travels along at normal highway speeds. The images provide a full view of the road and other assets. In transportation parlance, assets are signs, poles, pavement markings, and the like.

High-resolution revolution
The HD cameras can capture images at resolutions of up to 2448 x 2048 dots per inch. By comparison, high-end HD television resolutions are 1920 x 1080 dpi.

“The imagery is leaps and bounds ahead of what we had previously,” says O’Connor, who has 22 years with ADOT, the last six in photolog.

Using just one dashboard-mounted camera, the previous photolog van captured roughly 1.8 million photographs in 2008. Those images, along with GPS information added up to about 75 gigabytes of data. According to Bush, the new two-camera van took more than 3.6 million photos in 2009. Factoring in GPS and other information, the result was about eight terabytes of data—that’s almost 8,200 gigabytes.

“It’s a 100-fold increase in storage and data collected,” says Bush, who has been photologging for eight of his 11 years at ADOT.

Photolog project manager Jim Snow adds that the images are sharper.

“Now you can make out milepost numbers from 250 feet away,” Snow says. “It’s a 100 times better than the previous van. You can clearly see the details of a hex nut on a sign, that’s how good it is.”

In addition to the HD photos, Bush and O’Connor also collect Light Detection And Ranging data, or LiDAR, and highly accurate GPS information.

LiDAR is game changer
The main thing separating the new technology from the old is LiDAR, which has a wide variety of military and civilian applications. The HD cameras share space atop the van with two LiDAR lasers, one positioned horizontally to capture the roadway and the other positioned vertically to capture the roadside. Each laser takes 75 scans per second with each scan collecting about 10,000 points per scan. The points create 3D point cloud models of roadways, corridors and assets.

The 3D point clouds pinpoint the exact location of roadside assets such as signs, poles and pavement markings and give detailed information about each asset including its height, width and more. It can even compare point clouds from one year to the next, capturing any changes to assets. Snow believes that ADOT is the only state DOT using LiDAR technology for its photolog program, but the word is out. He’s been contacted by at least seven other DOT’s interested in learning about LiDAR’s potential.
**GPS on steroids**

Snow refers to the new van’s GPS system as “GPS on steroids.” It can calculate the exact location of the road and roadway assets in real-time with an accuracy of within 27 inches. After the data is processed, the accuracy increases to within 4 inches. If the GPS system malfunctions or it loses its signal, the van’s Distance Measuring Instrument and an Inertial Measurement Unit (IMU) continue tracking the van’s location, filling in gaps until the GPS system is restored.

Creating a visual inventory isn’t the only purpose of photologging. The Arizona Transportation Information System, commonly called ATIS, uses the data to update the “electronic centerline” or base road map for the state. The ATIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all types of geographically referenced information.

**Processing the data**

It takes about three months to process eight months worth of photolog data, a job that O’Connor and Bush used to do, but which is now performed cooperatively by Snow and GIS programmer Jarrod Celuch. They process the data and then provide it (the imagery, LiDAR and GPS data) to ADOT’s Information Data Warehouse, where those with ADOT intranet access can view it.

**Who uses it?**

Divisions and groups across ADOT tap into the rich storehouse of photolog data for a variety of purposes. The Asset Management group uses it to refine its huge inventory of roadway assets. The Signing Group is using it to help create a more complete and exhaustive sign inventory. The Risk Management office, as well as the Attorney General’s office, may use older and newer data for litigation defense. Materials Group and maintenance engineers can visually assess roadway conditions on office computers, rather than traveling to a site for inspections, which always carry a safety risk. Striping crews can use the data to determine areas where the highway needs to be restriped.

The photolog specialists logged certain “secondary targets” for the first time earlier this year. Such targets included frontage roads, traffic interchanges, ramps, and ports of entry. (There is even talk of logging airport runways.) In the past, the technology to capture these targets had not been developed.

**Bugs Are the Enemy**

“Bug hits are a big deal,” O’Connor says, “because the cameras are outside.” When bugs go splat, Bush and O’Connor pull over and clean the lens before resuming the photolog. Both recall a day last spring in Yuma when they encountered thousands of butterflies that forced them to shut down logging activities for an hour. “It was snowing butterflies,” Bush said. Wet weather also dampens logging efforts. “Any misting on the cameras makes them unusable,” O’Connor said.

**Funny looks**

With the cameras, LiDAR sensors, and GPS equipment on top, the van frequently draws double takes from pedestrians and motorists, some of whom immediately slow down mistaking the vehicle for a photo-enforcement van. As a precaution, the driver’s side, rear-quarter panel features the phrase “This is not a photo-enforcement van” in bold letters.

On logging days, the first order of business is to wake up the IMU system. This is accomplished by driving the van in figure-8 patterns six times around a parking lot or similar space. Typically, the team will do this in an ADOT Maintenance Yard if one is nearby, or in an empty parking lot out of public view. “We already look kind of different,” Bush remarks, “and when people see us driving in figure 8s, they really begin to wonder.”

*Continued on page 9*
Continued from page 4

Future
Bush and the others see an open road ahead for the photolog program. "You tell us what and where, and if the current van can get there, we can capture the data," Bush says. "And this technology is only going to get better."

Snow agrees. "The beauty of all this is that because LiDAR's application within the DOT space is so new, we're free to realize and develop all of it's possible implementations and utilizations," Snow said.

"ADOT now has the capability to quickly and efficiently capture its roadway asset's locations and attributes...all from the comfort of an armchair. From a safety standpoint alone, this is invaluable."

For now, the photolog team is eager to get the data into the hands of those who can put it to good use. "Our biggest fear is not if we can collect and provision this data, we've already proven that we can do this," Snow says. The challenge now is to ensure it will be utilized by the applicable divisions and groups within the agency.

For more information about the photolog van, contact Jim Snow at 602-712-8012, or jsnow@azdot.gov. Data from 2009, captured with the new technologies, is expected to be available sometime this month on the ADOT Information Data Warehouse website. For security reasons, it is only available to people with ADOT intranet access at http://iadw/.

WILDFLOWERS GONE WILD — ADOT’s Roadside Development section continually presents floral bouquets to motorists moving over the state highway system.

Although wildflowers populate the shoulders and slopes alongside the highways, the colorful vegetation doesn’t sprout up on its own. Roadside Development, under direction of manager and chief landscape architect LeRoy Brady, put it there. In urban areas, flowers grow from transplanted plants as well as seeded plants. In rural areas, they grow from seeded plantings.

Besides being pleasing to motorists, the wildflowers play a role in controlling erosion and crowding out weeds such as the Russian thistle, which after drying up breaks free of its roots and forms tumbleweeds.

Enhancing the landscape by beautifying areas disturbed by construction is a part of ADOT projects, such as the award-winning effort to widen U.S. Route 60 at Gonzales Pass east of Superior (see photograph above).

Some of the flowers in ADOT’s see mix include brittlebrush, desert marigold, desert globe mallow, Arizona bluebells, owl’s clover, desert senna, Mexican poppies, prickly poppies, bladdernard, and penstemon parryi.
Synthesis of Transportation Applications of Mobile LIDAR

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Keywords: mobile LIDAR, transportation, MLS, mobile laser scanning
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**Review**

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**Keywords:** mobile LIDAR; transportation; MLS; mobile laser scanning
The primary audiences of the document are management and staff who will be developing statements of work for MLS use in transportation.

Recommendation: Involve an experienced geomatics person throughout the entire process of using mobile LIDAR for a project.
Chapter 4 Workflow and Data Management
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  4.1.2 Georeferencing
  4.1.3 Post-processing
  4.1.4 Computation and Analysis
  4.1.5 Packaging and Delivery
4.2 Models vs. Point Clouds
4.3 Coverage
4.4 Sequential and Traceable Processes
4.5 Considerations for Information Technology
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  4.5.6 Software
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Chapter 6 Procurement Considerations
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6.2 Generic Cost Considerations
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  6.3.1 Owner/Operator
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7.5 Implementing the Guidelines
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7.8 Future Opportunities
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Recommendation: Follow developments in agency-wide collection and deployment of data, but at present adhere to the provisions of your sunset plan.
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Recommendation: Coordinate with other divisions/agencies prior to procuring mobile LIDAR services.

Recommendation: Perform a cost/benefit analysis and determine return on investment rather than focusing solely on the single project cost.

Recommendation: If parts of the workflow will be contracted out but others will be performed in-house, be sure that procedures will be properly coordinated with the data provider to minimize data transfer.

Recommendation: Always request a copy of the point cloud (at the highest level of processing completed) so that it is available for future data mining.
Recommendation: To streamline the adoption of MLS, a technology implementation plan should be developed.

Recommendation: Consider reengineering business processes and workflows to maximize the potential benefits of adopting MLS.

Recommendation: Consider forming an innovation group to address the evaluation and introduction of new technology.

Recommendation: Consider the use of pilot projects and the hiring of an independent consultant on the first few projects to advise and guide the process.

Recommendation: Consider the use of IDIQ contracts to pre-qualify service providers.

Recommendation: Consider the use of multiple sensors and platforms to maximize the return on data collection efforts.

Recommendation: Establish a staff training program as part of the technology adoption process.

Recommendation: When introducing new technology, the early adopters must be allowed to fail.

Recommendation: Document and publish the results of pilot projects so that others may learn from the process.

Recommendation: Be prepared to reengineer traditional 2D workflows to take full advantage of the new 3D paradigm.

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14.1.1 General Mapping and General Measurements
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14.2 Project Planning
14.2.1 General Planning
14.2.2 Roadway Analysis
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14.3.1 CAD Models and Baseline Data
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14.6 Operations
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14.7 Safety
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14.8 Asset Management
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14.10.1 Unstable Slopes, Landslide Assessment and Coastal Change
Quality Control Considerations

PAG is considering establishing permanent photo-identifiable Ground Controls for 2015 orthophoto acquisition.
## Available Guidelines

<table>
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<tr>
<th>Mobile LiDAR (Current)</th>
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<tbody>
<tr>
<td>CALTRANS Chapt. 15 Survey Manual 2011 Florida DOT 2012</td>
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<table>
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<th>Mobile LiDAR (Development)</th>
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<tr>
<td>TxDOT</td>
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<tr>
<td>ASPRS Mobile Mapping Committee</td>
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<td>MoDOT 2010</td>
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"The recently passed Map-21 legislation (Moving Ahead for Progress in the 21st Century Act, P.L. 112-141) provides financial incentives for the use of 3D technology (FHWA 2012). In addition, FHWA is also promoting the use of 3D through their Every Day Counts (EDC) initiative (FHWA 2012). This program is “... designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment.”

In the recently announced second round of initiatives, 3D modeling is highlighted. As stated on the program website, “As the benefits are more widely recognized, many in the U.S. highway industry will transition to 3D modeling over the traditional two-dimensional (2D) design process” (FHWA 2012).

In addition to using mobile LIDAR to collect and document the as-found conditions prior to construction, it also holds promise for supporting the construction process itself. Significant reductions in the cost of maintenance and protection of traffic can be achieved through the use of mobile LIDAR versus traditional survey methods as well as in measuring quantities.

As agencies transition to 3D there is also the opportunity to move to an all-digital construction environment. The availability of mobile devices such as tablet computers and smartphones will help to support this transition.”
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Keywords: mobile LIDAR; transportation; MLS; mobile laser scanning
3.3.5. Software Considerations

four tasks that should be possible in various point cloud software programs:

(1) All data should be organized into one project where it can be processed and archived;

(2) The data should be viewable on different scales, such as micro-scale point clouds and a full project area (e.g., as a rasterized data set);

(3) The software should allow for geometric correction of the various sensors via a strip adjustment;

(4) The data should be able to be exported in many different formats, including standardized formats such as ASCII, LAS, and E57, to be compatible with other software.
3.3.5. Software Considerations

Some of the most common, but far from inclusive, software manufacturers are:

- Autodesk
- Bentley
- Certainty 3D
- ESRI
- Innovmetric
- LAStools
- Leica Geosystems
- Maptek
- Riegl
- Terrasolid
- Topcon
- Trimble
- Virtual Geomatics
Certainty 3D

http://www.youtube.com/watch?v=xkXq2QzBkNY&t=0
http://www.certainty3d.com/videos/Rey/Hqvideo/video.html
Virtual Geomatics

http://www.youtube.com/watch?v=2FtAeM7atsQ&list=PLAF1944FB108B93E4
Virtual Geomatics

http://www.youtube.com/watch?v=cusfn6yHfa8
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Mobile Mapping Solutions for Design & Asset Management, Woolpert May 2013:

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http://azmemory.azlibrary.gov/cdm/ref/collection/statepubs/id/5531

NCHRP Report 748:
Guidelines for the Use of Mobile LiDAR in Transportation Applications
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_748.pdf

Synthesis of Transportation Applications of Mobile LIDAR, 2013:
http://www.mdpi.com/2072-4292/5/9/4652

Software:

Certainty 3D
http://www.certainty3d.com/mediacenter/?tab=0

Virtual Geomatics
http://www.virtualgeomatics.com/index.html
Questions?