Mobile LiDAR Scanning for Transportation Design Purposes

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Finalist for the David Thompson National Geomatics Awards in the Categories of Innovation in Geomatics *and* Unusual Application in Geomatics.

The Ministry of Transportation of Ontario (MTO) resurfaces over 1000 km of highways each and every year and the foundation of every resurfacing project is an accurate and complete engineering survey. New technology has demonstrated several advantages over conventional data collection methods in areas such as time constraints, worker safety, quality control, and cost savings.

In the fall of 2011 the MTO (Northwest Region) engaged Tulloch Geomatics to complete 85 km of engineering surveys of primary and secondary highways throughout Northern Ontario. The timelines to complete the engineering surveys for this project were short. The project was awarded in the middle of September and snow often arrives in Northern Ontario in late October or early November. Tulloch was cognisant of the fact that the use of conventional surveys would not likely allow the surveys to be completed before snowfall. For this reason, Tulloch proposed the use of Mobile LiDAR Scanning (MLS) to MTO as an innovative means to ensure the topographic data was captured in snow free conditions. This was the first time that the MTO used MLS on one of their Group Work Projects.

Google Street View shows an area of the project as it appears in google street view.

After horizontal and vertical project control was established by Tulloch Geomatics crews, the MLS mounted vehicle was mobilized to each highway segment to collect high resolution topographic detail. The MLS vehicle consists of 2 Riegl LiDAR (lasers) sensors, 2 digital frame cameras, a dual frequency GPS receiver, power source, digital display, and a high accuracy inertial navigation system (INS). The digital cameras were set to collect images every 1 second, and the GPS and INS recorded positional information 1 and 200 times per second, respectively. Two dual frequency Sokkia GRX-1 GPS receivers were set over project control while the MLS truck simultaneously drove the highway segments. The maximum base line distance between the GPS receivers and the mobile sensor was set at 5 km. For each highway segment the MLS vehicle made at least 2 passes (typically eastbound lane and westbound lane) to ensure redundancy throughout each highway segment. The raw LiDAR data, the GPS and INS positional information, and the digital imagery were processed to produce a LiDAR point cloud and geo-referenced digital images.

The use of MLS allowed the topographic detail of all five highway segments (totalling 85 km) located throughout Northwest Ontario to be field surveyed in 7 days, as opposed to a forecast conventional (GPS/levels) survey duration of at least 120 days. The use of MLS on this project allowed the surveys to be completed in a matter of days, rather than months, allowing MTO's Capital Projects Schedule to remain intact with surveys being completed in 2011/ 2012, engineering design to be completed in 2012, and construction to commence in 2013.

The safety of survey crews has always been an important aspect of completing any survey within a road right-of-way. Traffic control and signage can mitigate risk and keep workers safe; however, new technology can take them outside danger zones altogether. With the use of MLS it is possible to drive at highway speeds while collecting 600,000, 3-D points per second. The use of MLS allows data collection to take place on the hard surface of the road from the comfort of a vehicle without the need for workers to be standing or walking within the driving lanes. This provides a level of safety (and comfort) to the survey crew that would not have otherwise been available to them. Hard surface data has typically been collected by total station or Real-Time Kinematic (RTK) GPS methods. Neither one of the conventional methods can compare to the use of MLS where safety is concerned, nor when it comes to the efficiency of data collection.

As part of Tulloch's QC process on the LiDAR data,

RGB PC shows the colourized point cloud

target validation points are set every 250 meters along the road corridor, surveyed conventionally, and then compared to the LiDAR data. The intent of this QC process is to demonstrate that the LiDAR data is consistently below the required 2cm accuracy level, both horizontally and vertically. Additional cross-sectional audit data is captured using total station methods every 500 metres to further demonstrate that the LiDAR data is consistently below the required 2cm accuracy level. In the event that the collected LiDAR data does not match the validation points to the desired specification, it is also possible to perform an adjustment on the data, which will hold the validation points as fixed reference points and adjust the point cloud to fit these points. This is typically required when there is a control bust with provincial or federal control points.

Once the accuracy of the point cloud is confirmed, feature extraction can commence. From the highly accurate geo-referenced LiDAR point cloud, highway features (crown, edge of pavement, edge of shoulder, rock cuts, etc) can be extracted. The digital imagery is also used to map RGB colour values onto the LiDAR points to produce a colourized point cloud in addition to the more common signal intensity view, which displays colours based on the intensity of the returns. LiDAR analysts use a combination of different point cloud views (top down, cross section, 3-D orbit, colour intensity, and RGB colourized points) and digital imagery to interpret, extract, and classify the data. Similar to conventional

Colored Intensity PC shows the colour intensity point cloud

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A portion of the completed base plan which corresponds to the area shown in the other images

surveys, this process produces point files which were converted to AutoCAD Land Desktop Development (LDD) Field Books and then imported into AutoCAD LDD. Base plans and profiles are generated from the survey information and submitted to the MTO or the municipality, which will in turn be passed on to the Consulting Engineering firm that will design the highway or road project.

There are areas that require conventional topographic surveying (in-fill) for various reasons. For example, areas of open water tended to absorb the laser signal and do not provide adequate returns to accurately delineate the shoreline. This is especially true of marshy areas. Other areas that required in-fill included areas of thick vegetation (where the laser could not penetrate to the ground surface), drainage features such as culverts (as they were not typically visible from the driving surface), and the tops of tall rock cuts where there was no line of sight between the ground surface and the MLS system.

The use of MLS can provide a cost savings during the Field Audit or Quality Control review of the project. The LiDAR data and digital imagery provides an (almost) complete record of the features present along the road with the exception of the areas listed above. It is a valuable tool for performing a portion of the Quality Control for the project by cross-referencing the features delineated on the base plan with the features in the LiDAR data, to ensure all features have been extracted properly. LiDAR analysts were able to return to the point cloud to confirm features without the need to return to the field. The digital images that are taken by the system also proved to be a valuable reference tool. MTO, or other clients, are also able to employ these tools while reviewing the plans.

The vehicle mounted MLS system

The potential cost savings of the use of MLS is three fold. First, the data collection is performed much faster than conventional surveying which can help to reduce costs. Second, the point cloud data and photos can help to confirm features which can in turn reduce the number of trips to the field to confirm and collect additional data. Third, where traffic control would normally be required in order to perform a topographic survey, the MLS system does not require traffic control as it is able to travel at highway speed while collecting data.

Tulloch's innovative approach to Engineering Surveys was nominated for two of the David Thompson National Geomatics Awards. The project was nominated for the "Innovation in Geomatics" and "Unusual Application in Geomatics" categories and was declared a finalist in both categories. Certificates were awarded in recognition of the finalist achievement.

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