Using Mobile Lidar to Survey Railway Infrastructure.
Lynx Mobile Mapper

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Key words: Lidar, Mobile Mapping, Railway, 3D.

Summary
This project proved that the Lynx Mobile Mapper can quickly acquire geo-referenced 3D spatial data on railway infrastructure from a platform mounted on a moving rail car. Lynx Mobile Mapper data meets survey-grade criteria, providing sufficient detail and accuracy to extract essential spatial information for engineering, maintenance and construction applications.

Proof of Solution

When a large-scale project requires survey-grade spatial data, lidar (Light Detection and Ranging) has proven to be the fastest and most accurate technology for mapping and modeling. Over the last decade lidar technology has evolved to meet the needs of a broad range of survey applications. From underground mining to urban planning, hydrographic depth charting, airborne terrain mapping and all the way to the surface of Mars, laser ranging instruments have been accurately measuring distances and capturing images with increasing speed and precision.

Recently, terrestrial lidar imagers (T-Lidar) have advanced from a stationary tripod-mounted set-up to a new stage of mobility, enabling surveyors to capture highly accurate geo-referenced 3D spatial data from a variety of platforms, including land and marine vehicles.

Curious to learn more about this development, Aerial Data Service (ADS), of Tulsa, Oklahoma, contacted Optech Incorporated to test its Lynx Mobile Mapper in an untried application: surveying railway infrastructure from a moving rail car. In some cases, a client may present a surveyor with a detailed set of project requirements. Among these requirements, the client might specify the deliverables: raw data, file formats, Digital Terrain Models (DTM), Digital Elevation Models (DEM), topographic maps with set contour gradients; requirements for accuracy, resolution, density, cost and time estimates. Based on the specified requirements, the planner determines the most efficient and cost-effective survey.

In a new, untested application, however, it may be premature to anticipate highly specific requirements.

In this instance, ADS did not request a detailed set of requirements. Instead, they were interested in a "proof of solution". First and foremost, they wanted to determine whether Optech's Lynx Mobile Mapper could provide 3D spatial data with sufficient detail and accuracy to extract rail information for use by maintenance and inspection services. ADS was particularly interested in examining Lynx Mobile Mapper data for its potential in **monitoring track conditions, switch conditions, inventory, signage, and obstructions such as vegetation encroaching on the rail right-of-way**.

In addition to the areas of interest identified by ADS, the gathered data demonstrated that the Lynx Mobile Mapper offers untapped potential for multiple uses in railway surveying applications. A number of key areas are identified as being especially suitable for further exploration. These areas include rail **corridor design, corridor monitoring, hydrostatic and hydrokinetic monitoring**. Some of these potential uses are discussed in this paper. It should be noted, however, that in the absence of specific requirements, the acquired data has not yet been subjected to rigorous test standards.

Rail corridor design

Figure 1: Rail corridor surveyed by Lynx Mobile Mapper outside Tulsa, Oklahoma

The design of new railway sidings is crucial to improving traffic flow along existing rail lines. Rail sidings provide train engineers with the necessary space to either stop and wait for higher priority traffic to pass on a single rail line, or drop cargo for transfer or unloading. In either case, the need to add rail sidings to existing track means that an accurate survey is required before proper design of the new rail siding can proceed. Conventional survey methods are time-consuming and require either that the line be shut down for safety reasons, or that data collection be interrupted to let traffic pass. Mobile terrestrial-based lidar offers a solution to performing this task safely and efficiently, without interruption.

Attempts to use airborne lidar for monitoring and designing railroad infrastructure have been made in the past. However, the accuracy of the lidar data collected from an airborne platform was less than adequate (Fateh and Jones). Now, with the advent of mobile terrestrial-based lidar, a more accurate and cost effective method of collecting railway corridor data for design purposes is available.

In order to test the performance capabilities of the Lynx Mobile Mapper, ADS arranged to scan a section of railway outside Tulsa, Oklahoma. The Lynx Mobile Mapper was mounted on a speeder (track-maintenance car) where it traveled approximately 5.5 km (3.4 mi) of tracks, scanning the area surrounding the rail line with one of its lidar sensors (Figure 2).

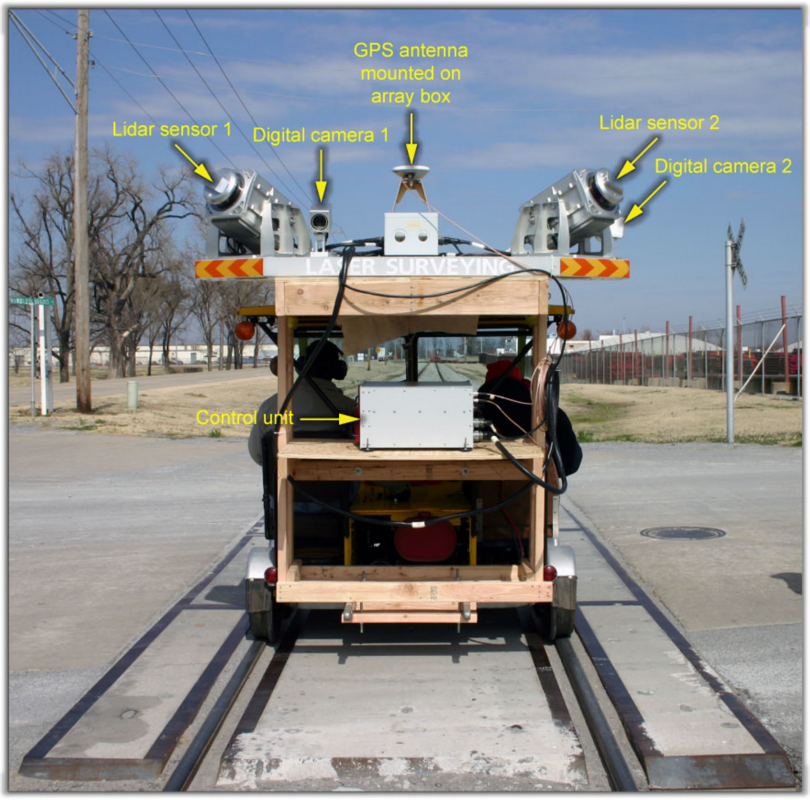

Figure 2: Lynx Mobile Mapper mounted on railway speeder

From the data collected during this project, several useful portions were extracted from the resultant point clouds. Topographic contour maps (e.g., Figure 3) of the surveyed rail line were output after processing the raw XYZi (Northing, Easting, Height and Intensity) data using the commercially available software package, Terrasolid.

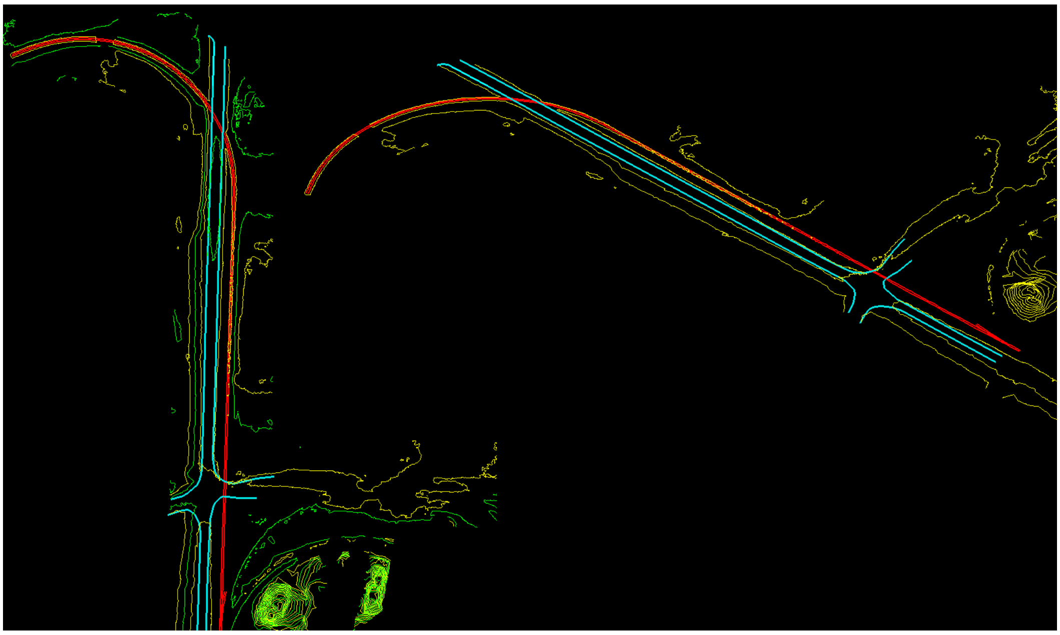

Figure 3: Contour lines made from Lynx Mobile Mapper data captured from a moving speeder on a section of railway track; contour separation 0.5 ft. (left), 1-ft. (right)

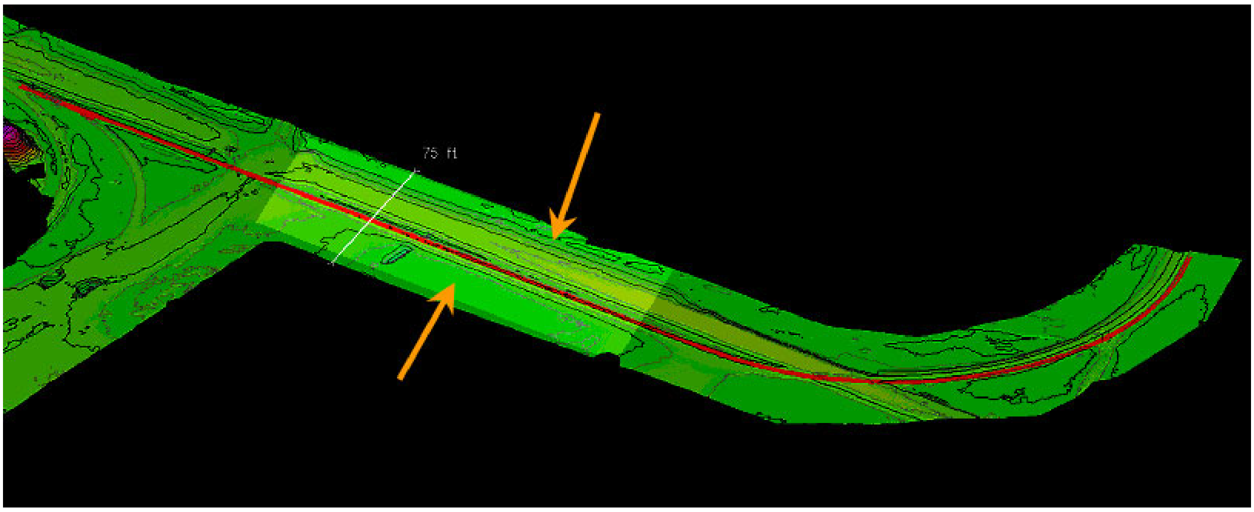

Figure 4: Triangulated Irregular Network (TIN) model with 1-foot contour lines showing a 75-foot corridor along a section of rail line

These topographic maps and models give surveyors and engineers a starting point from which a number of different design and monitoring projects can be based. As shown in Figure 4, the map can be used to estimate the volume of fill that will be needed when adding a siding or spur line to the existing structure.

For planning purposes, the information gleaned from these topographic maps is invaluable. For example, in Figure 4, the tightly banded contour lines in the highlighted area above the (red) track reveal a more pronounced change in elevation. Therefore, the grade in this area may be too steep to accommodate a parallel set of tracks. Similarly, the more broadly spaced contour lines below the track suggest flatter terrain, more suitable for laying additional track; however, if this area is very low it could be subject to flooding, so engineers would have to determine the suitability of the surface material for supporting any additional tracks.

Diesel train engines cannot easily climb grades steeper than 2% (Beranek); therefore, new rail sections must closely match the elevation of the existing track. The advantage that lidar data provides to the designer is the ability to repeatedly extract height differences directly from the original point cloud. The 75 ft. cross-section in Figure 4 can be moved to any point of interest so that the surveyor can examine details at any point along the scan.

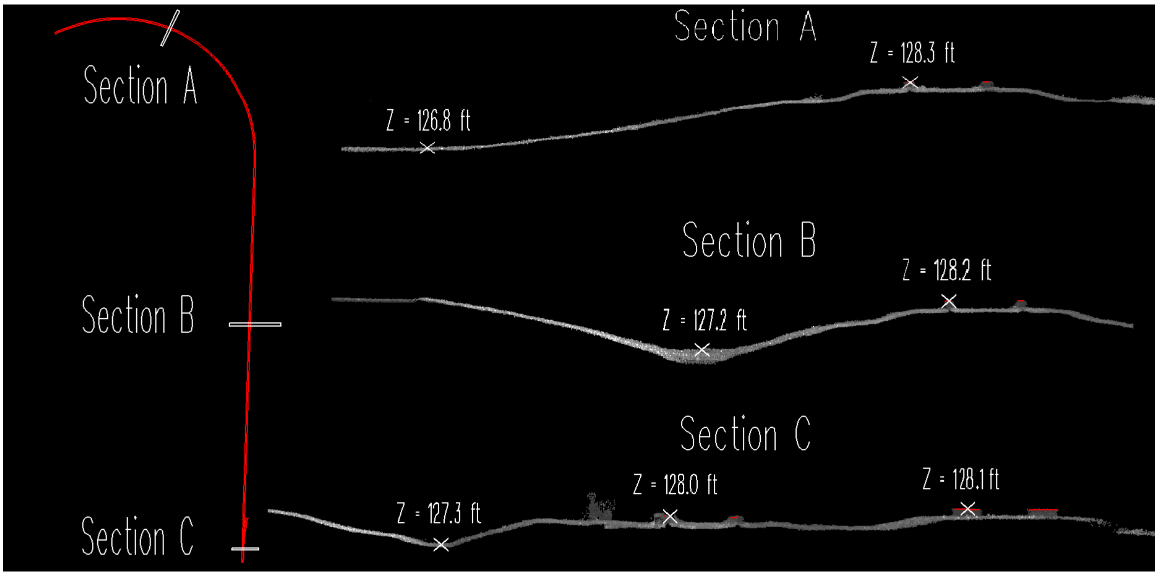

Figure 5: Cross-sections showing top rail elevation compared with lowest point along rail corridor.

Figure 5 shows elevations extracted for the top rail and low point on cross-sections of the scanned rail corridor. These cross-sections can be easily cut at whatever position and frequency the user requires.

To acquire this data in the conventional way, a surveyor would have to set up a Total Station and traverse for each cross-section. The resulting cross-section measurements apply only to those points surveyed. Other areas of interest require separate surveys. This limitation can be contrasted with the multitude of data acquired in one pass by the Lynx Mobile Mapper. The user can confirm elevation measurements at any point of interest along the scan by moving a cursor in the post-processing interface. A Lynx data set provides a permanently searchable data base after each survey.

Hydrostatic / Hydrokinetic Monitoring

The topographic maps generated from the Lynx Mobile Mapper can also be used to monitor existing drainage patterns along the track bed. Several sources—Langley et al, Beranek, Hay—stress the importance of proper drainage to the stability of the sub-grade material supporting the railway track.

In the United States, standard gauge railway track consists of individual 39-ft. long sections spaced 56.5 inches apart. These rails sit on rough timbers that are embedded in ballast that consists of sand or gravel supported by sub-grade material of a highly variable quality. The variable quality of the soil in the sub-grade material is usually site-specific, as this material is built up from the area soil surrounding the rail corridor.

The main purpose of the track is to disperse the surface stress of the train wheels to a point where the sub-grade material can support it (Hay). Hay states that reasonably firm sub-grades have a supporting capacity of about 20 psi. If the sub-grade material, upon which the rail track rests, is undermined by water, the supporting capacity of the soil can be greatly reduced from the 20 psi level.

The concentration of stress that a track must disperse is a function of the combined speed and weight of the vehicle traversing it. The sub-grade's ability to support rail traffic diminishes over time due to the cyclic nature of the dynamic load, inappropriate vehicle speeds and/or weights, or deterioration of the track or sub-grade caused by prolonged exposure to extremes in weather and climate.

The topographic maps generated by the Lynx point cloud data contain a wealth of information essential to designers. The maps can serve as the basis for analyzing current water flow patterns in the rail corridor. Such flow patterns will indicate where the sub-grade material is at risk of being undermined through erosion by flowing water, or through the capillary action of water in soil. This last consideration is especially important in environments that experience freeze-thaw cycles, and where the soil is made up primarily of a silt-clay combination, as in many parts of southern Ontario.

Rail corridor monitoring

Every railway line is unique, in that each supports a site-specific ecosystem. Various components of an ecosystem can become problematic when they impinge on the safe and efficient use of the railway corridor. Unchecked vegetation growth (e.g., massive tree roots) along the rail corridor can undermine the stability of the sub-grade material. On the other hand, some vegetation can also provide a needed mechanism to resist the effects of erosion. However, depending on their location, trees along the rail corridor can also interfere with passing trains by obstructing the free passage of rail vehicles.

In the United States, the maximum height of railway vehicles is 15 feet, 6 inches, with a maximum width of 10 feet, 9 inches (Horobin). Using the lidar data collected outside Tulsa, Oklahoma, measurements of tree heights close to the rail line could be ascertained. Figure 6 shows the height and distance of various trees measured from the top center of the closest rail along the surveyed corridor.

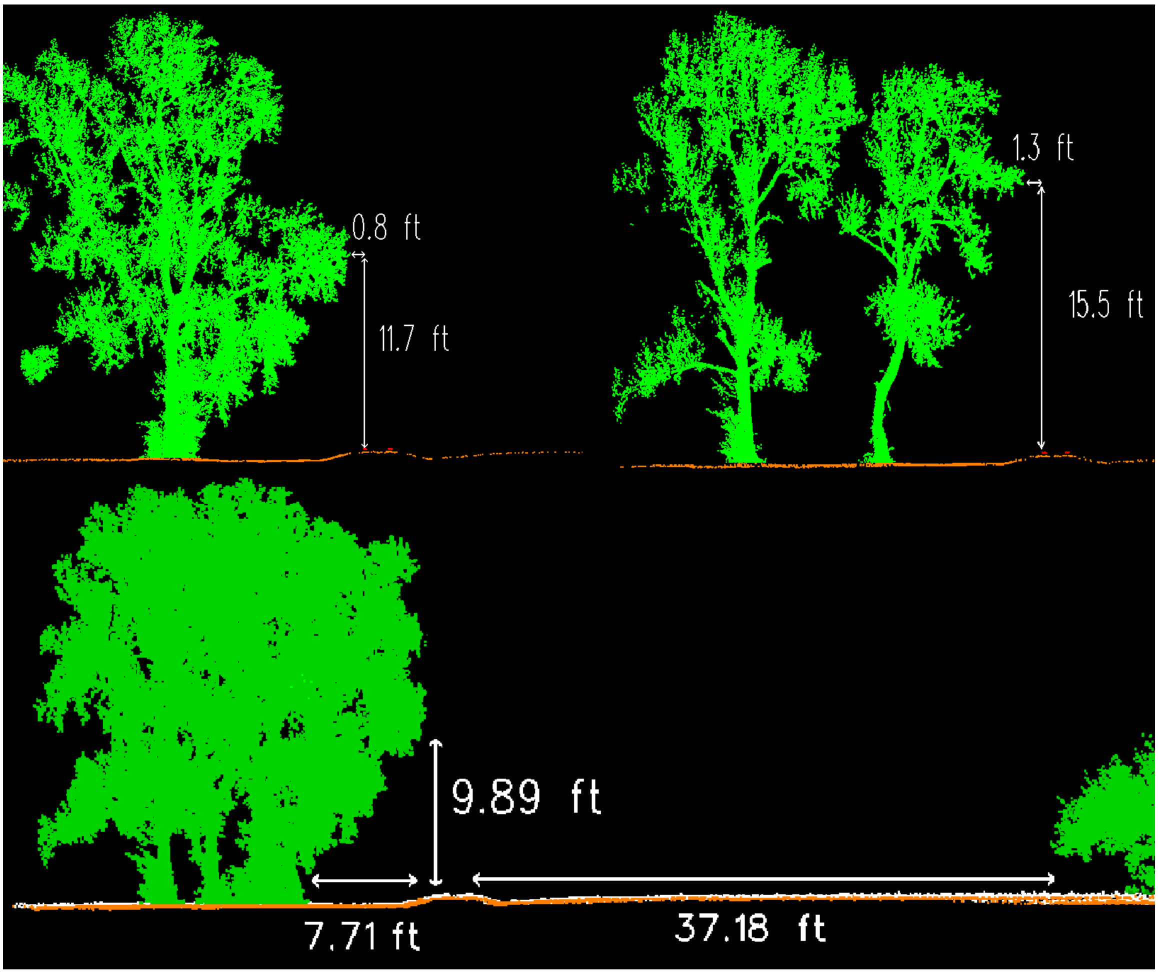

Figure 6: Various tree heights above top of rail, plus distance of trunk from top center of rail.

The measurements shown in Figure 6 indicate that there are potential problems with some of the vegetation alongside the track. Where the height of the vegetation is less than 15 feet, trimming or removal may be necessary.

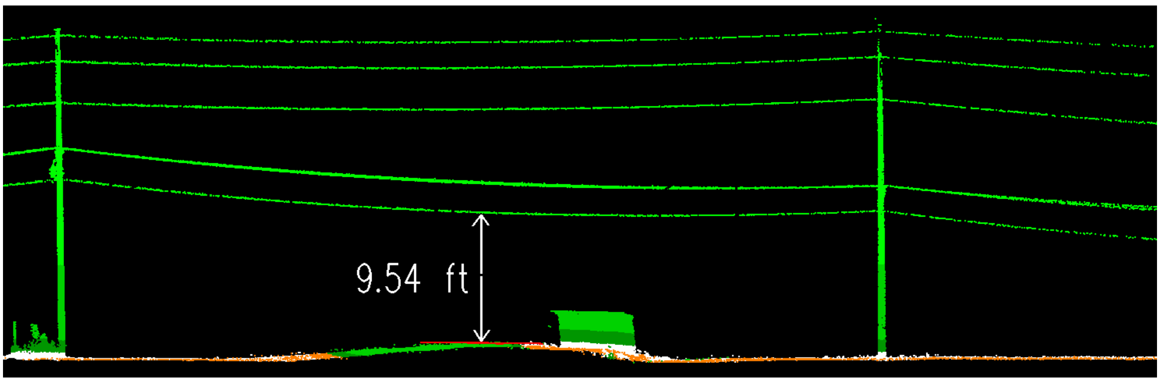

Figure 7: Height of overhead wires above top center of rail.

Along with natural obstructions, man-made features overhanging the track may also pose a risk. Figure 7 shows the measured distance from the top-center of a rail to overhanging wires above. The clearance between the tracks and the wires limits the height of rail cars that can travel along this line.

Conclusion

At the time of this project, the client had expressed a desire for an overall "proof of solution". Therefore, the data acquired here has not yet been subjected to the rigors of systematic testing. Nevertheless, it was demonstrated that terrestrial-based mobile lidar offers untapped potential for myriad uses in surveying railway infrastructure, including:

- Surveying an area of interest quickly, safely, efficiently and without the larger scale interruption necessitated by traditional survey methods
- Rail corridor design
- Rail corridor monitoring
- Hydrostatic and hydrokinetic monitoring
- Volume estimation (amount of fill needed to add for the construction of a new spur line)
- Extracting height differences repeatedly from one point cloud
- Measuring the height and proximity of trees and man-made objects surrounding the rail right-of-way.

Presently, additional projects and demonstrations at other locations are being scheduled. Considering all the recent discussion regarding investment in large-scale infrastructure projects, Optech looks forward to working with surveyors and engineers to provide them with the best tools for improving rail infrastructure quickly, efficiently, accurately and safely.

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