The Application of Lasers to determine Structure Gauge Encroachments

Biography – David Petterson, B. Geomatics, University of Melbourne

David Petterson, Business Development Executive, Geomatic Technologies

Prior to undertaking a business development role at Geomatic Technologies (GT), David was the Senior Project Manager for many of the rail infrastructure projects undertaken by Geomatic Technologies since 2004; including the Victorian Rail Infrastructure project that was successfully completed at the end of 2006, and was awarded the Asia Pacific Award for Spatially enabling government.

Abstract:

Reflectorless high speed lasers have been deployed on various projects throughout Australia and New Zealand to define trackside asset encroachments. Laser hardware is configured with positioning and camera equipment on hy-rail and locomotive platforms to record range data from the track to nearby assets such as bridges, signals and platforms. The raw laser data can be tagged with a track chainage and then used against the prevailing straight or curved track structure gauge envelope to generate an encroachment report.

Geomatic Technologies have completed structure gauge encroachment surveys throughout Victoria’s rural and metropolitan networks on behalf of the Victorian Department of Infrastructure, and the results have been incorporated into the PASS (Privatised Arrangement Support Systems), Assets Information System

This case study will review logistical issues involved with a state-wide laser projects, describe the innovative techniques used for capture and data processing against industry standards as well as illustrate the way the data is used by PASS system users
INTRODUCTION

Since 2003 the Victorian Government of Australia, through the Department of Infrastructure (DOI), had undertaken a state wide asset inventory of all infrastructure contained within the rail corridor. This was in response to the government having outdated and fragmented information of the condition of the rail assets prior to leasing the infrastructure as part of the privatisation process which began in the early 1990's.

The state wide infrastructure project involved the collection of imagery, location and attribute information for every asset within the lease hold area of the entire rail network. The data was to provide the foundation for a secure web-based mapping portal called PASS (Privatised Arrangement Support Systems). The data collected for the PASS Assets system was supplied using innovative survey techniques by integrating digital imagery with advanced position systems all mounted on a track inspection vehicle that regularly accessed the entire network. Although very successful in its mission, many lessons were learnt in relation to capturing so much data across a wide area which could be applied to other state wide projects.

With the acceptance of the PASS system growing rapidly throughout the organisation, more rail based information was requested to be input into the system. The state government initiated a second project which was to perform a structure gauge encroachment survey of the states network. The Structure Gauge provides a safe profile for the passage of rail vehicles and loadings which conform to a defined set of rolling stock outlines. This structure gauge survey was to determine where any encroachments might occur based on the current standard maximum gauge templates.
Any encroachments detected as part of the survey were to be referenced to the newly mapped rail network within PASS Assets, and also to have an image and description of the encroachment attached for reference and auditing purposes.

Historically, existing methods for detecting encroachments in the rail corridor tended to be “contact” systems which were quite labour intensive and limited in their ability to interface with other systems.

This project provided the opportunity to implement technology which had been used successfully on other projects and to test a new “non-contact” system for the detection of encroachments that could be integrated into these other systems.
PROJECT BACKGROUND

In 2003 the state department initiated a data capture survey for the entire Victorian rail network. During this first state wide data capture project, the technology used involved the synchronization of high resolution digital still imagery, with positional systems on board the rail vehicle. The positional data collected in the field, was firstly processed using a robust kalman filter, to generate a smoothed track centreline. This centreline would then be processed again using curve fitting software which applied geometric curves, transitions and straights to the smoothed centreline.

The result would be an accurate track alignment which was connected in discrete geometric track segments.

The accurate track alignment would provide a framework for referencing all other data, including the high resolution digital still imagery.

Individual image frames were referenced to the track centreline and the imaging cameras were calibrated to support accurate mapping through photogrammetric techniques.

These sequenced image frames served two purposes. The first was to provide an operator coordinated rail imagery linked to a common map base for visual inspection of the track. The second enabled the operator to accurately map, and attribute, point, line and polygon features that could be identified within the imagery.
Much of the technology and processes that were developed and used on this project would be required to implement the new structure gauge project. Similarities in the specifications between the two projects meant that certain information could be re-used which would greatly reduce office processing time, and remove the need for duplication of existing data.

**INNOVATIVE APPLICATION OF LASER TECHNOLOGY**

For the state wide structure gauge project the use of inexpensive non-contact pulse laser measurement technology was used across the Victorian rail network. These lasers were mounted to a rail vehicle to record continuous rail profiles as the vehicle travelled along the track.

The system used two 180 degree lasers which are mounted back to back and synchronized...
to record a near 360 degree profile of the track corridor. The lasers continuously scan; recording distance measurements from any objects they encounter out to a 26 ft (8 m) radius from the centre of the track. The units are built to withstand harsh environments and can operate in a wide range of lighting conditions from bright daylight through to dark tunnels. As each laser scans through its 180 degree cycle, the data stream from both lasers is combined creating the near 360 degree scan which is then stored as one discrete profile.

This profile is referenced to the other systems on the recording vehicle, which at the same time are recording the position and orientation of the vehicle as well as capturing imagery from high resolution digital still cameras. With the exception of the lasers, the data acquisition systems used are the same as the ones from the first asset mapping project.

At the end of a recording session the position, image and laser data is transferred to the office for post processing.

The position and orientation data is processed using the kalman filter to produce a smooth track centreline and a link is created between this centreline and the discrete laser profiles. Laser data is processed by taking the discrete raw laser profiles captured in the field and translating them so that they are orientated with reference to the track location from where they were recorded. The outcome of the laser data processing is a database of track profiles which are spatially located along the track centreline.
The laser profiles are now linked to both a spatial reference system as well as the geo-referenced imagery. By spatially referencing the laser profiles it allows an operator to view the profiles through a map interface or overlay the laser profiles in the train based imagery.

PROCESSING THE GAUGE ENVELOPE

The encroachment detection process involved the application of different gauge envelope templates based on the geometric alignment of the track. Curves of differing radii and direction (left / right) required separate templates than that of straight track, also a different envelope template was to be used where overhead wiring was present. Per the state defined structure gauge standards, a total of 10 discrete gauge profile templates were applied based on the conditions listed above.

The existing alignment of the track contained much of the information required to determine which of the ten available profiles the correct one to apply was. This information was part of
the attributes of every track alignment segment created during the curve fitting process from the first asset mapping project.

Using this information, the laser software was able to automatically review the track alignment at every laser profile location, and select the correct structure gauge template for that particular point based on the track geometry. Information such as the existence of overhead wiring, required an operator to select which templates to use at the beginning of a track section, but this was a relatively simple process since over 90% of the network was non-electrified.

Once the correct template had been established for a discrete laser profile, the software would automatically overlay one on top of the other. This template is then used as the defining polygon for the encroachment detection process. Every laser point is analysed in the profile to determine whether it’s within or outside the polygon. Should the software detect a laser point within the gauge envelope it will tag this profile as an exception and include it in a list for an operator to review.

![Figure 8. Screen grab of laser profiles referenced to a map base and track imagery](image)

The tagged encroachments detected by the system will have a geographical coordinate attached to it so that it can be visualised on a map base. This enables the operator to view the encroachments as they exist in the real world. As the train based imagery is also linked to
this system, the operator can “drive” the rail corridor to a tagged encroachment to see what it might be. The operator can then make a determination whether it’s a valid encroachment and select the best image of it using the track based imagery and link it to the laser profile.

Invalid encroachments may exist in several forms. Long grass, and other light foliage will show up in the lasers profiles, along with temporary encroachments such as track maintenance workers and machinery. These were not considered to be valid and as such were excluded from the final deliverable.

By applying automated routines to sort through the laser profiles, the operator is only required to review several hundred possible encroachments per track section, rather than several hundred thousand individual profiles. It also provides the operator with a reference so that they can consult others in the determination of a possible encroachment.

Overall 3,000 miles (5,000 km) of track was mapped and processed in a relatively short time frame, producing an extensive list of encroachments for input into the DOI’s PASS Assets system. The deliverables to the government consisted of a series of tabulated records which detailed the type and location of each encroachment, along with its associated laser profile, and track based image. While the majority of encroachments consisted of trees and other heavy foliage near the track, there were also many instances of platforms, signs and other structures which were encroaching within the standard max gauge envelopes.
CHALLENGES AND ISSUES

Track Access & Vehicle Types

Accessing the rail corridor for survey purposes is always a challenge due to the prioritization of freight and passenger services over all others. The use of different vehicles can assist with obtaining better access to rail corridors and can also dictate the speed at which the survey can be completed. For instance, the use of a hy-rail can be advantageous as the vehicle can do discrete sections of track without having to traverse the entire network to get to it. It may also be easier for clearance to be given to work in an area as you can move on and off the network. In other areas, (i.e. city subways) a hy-rail may be restricted to night work only or banned from the network all together, so the use of a locomotive is the only option. In most cases Locomotives can travel the networks at a faster speed than hy-rails, but are more rigidly controlled for access along the rail corridor.

By designing the data capture systems to be easily transferable between different rail vehicles the advantages of both types of vehicles was effectively utilised for the structure gauge project.

Imagery Acquisition & Validation

For the first asset mapping project the imagery was a critical part of the mapping and validation process, as well as being a deliverable to the client. Imagery by its nature is subjective to the person viewing it and so it is important that good imagery be acquired which led to forced cancellations of scheduled runs due to poor lighting, rain etc.

The acquisition of good imagery presents many problems due to the fact the lighting conditions will vary tremendously based on time of year, orientation of the sun with respect to the position of the camera, and other issues, like getting obstructions on the camera lens (i.e. dirt, bugs).

The asset capture project used cameras mounted both forward and to the rear of the mapping vehicle to double its chances at collecting good imagery. From this project comprehensive track imagery of the corridor was available for the structure gauge project.
The collection of laser data and positional data could be captured at any time of day or night. To take advantage of this the survey was performed at all hours of the day, and in any light condition. Although cameras were used on the laser survey, these were to provide supplemental coverage to the initial rail imagery.

This worked well in the majority of cases, however due to the time difference between, the capture of the imagery and the collection of the laser data, a few exceptions would invariably show up. This is where a laser profile showed something encroaching in the corridor, but the associated imagery from the same day was not viewable, and the previous imagery showed nothing that would cause the obstruction shown.

The above profile and associated image, best shows how a temporary obstacle captured using the laser system, would be difficult to comprehend if there was no imagery taken at the same time to verify its existence.
CONCLUSIONS

The use of laser technology combined with an integrated image and location system, proved to be a successful combination for completing state wide structure gauge survey. With the entire rail network now having been surveyed, the DOI are looking to reuse the laser data to perform other analysis. The laser data has been used on new construction jobs, to ensure contractors, have excavated the correct amount of rock, and earth to ensure minimum standards are met for gauge clearance. There are also plans to use the data to perform clearance reports from rolling stock to structures like platforms and bridges. Laser data is also needed for planned electrification works, tunnel engineering and double track works.

![Figure 12. Screen grab from the PASS Assets system](image)

The encroachment data along with other rail conditional information such as rail head wear and ride quality information is being added to the PASS Assets system. This information along with up to date imagery, and asset data is providing strategic overviews of the rail network.

With advances in the technology and techniques for acquiring and collecting rail based information, it is becoming easier for organisations to build up a comprehensive view of their networks which can be easily updated for effective asset management and auditing purposes.
REFERENCES
