Application of Laser Scanning in the REDUS Layout

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Summary

Laser scanning is a modern surveying technology allowing to obtain the surface of an object with high accuracy, point density and speed. Nowadays this method is actively applied in many spheres. Railway industry is one of them, in which this method is used for large-scale topographical mapping, creation of longitudinal profile, certification of rail infrastructure objects and in this paper rail track monitoring. Rail track monitoring requires the highest accuracy. For reaching an appropriate accuracy laser scanning should be carried out with high accuracy scanners using special targets as control points and keeping certain approaches. To guarantee high accuracy some control and check measurements are usually done. One of the places in which laser scanning method was started to be applied is the REDUS layout, where GNSS receivers and position sensors are tested, calibrated and validated statically or dynamically. In the paper the results of laser scanning application in the course of the regular base measurements for REDUS are presented. It is shown, that the method allows to represent a structure like rails with high precision.

Zusammenfassung

Laser Scanning ist eine moderne Technologie zur Vermessung von Objektaußenflächen mit hoher Genauigkeit, Punktdichte und Geschwindigkeit. Sie findet Anwendung in den verschiedensten Bereichen. Der Eisenbahnsektor ist nur ein Bereich, in dem diese Methode häufig angewendet wird für große, topographische Aufnahmen, Längsprofile, Beweissicherung von Objekten der Infrastruktur und in diesem Fall für das Monitoring der Schienen. Das Monitoring der Schienen stellt höchste Ansprüche an die Genauigkeit. Um diese zu erreichen, braucht es gute Scanner und die Aufstellung von Zielmarken als Passpunkte und auch eine spezielle Messungsanordnung. Zur Verifikation sind Kontrollmessungen notwendig. Einer der Orte, in dem die Methode Anwendung fand, ist die REDUS-Anlage, in der GNSS-Empfänger und andere Sensoren statisch und dynamisch getestet, geeicht und validiert werden können. In diesem Beitrag wird eine Anwendung des Laserscannings vorgestellt, die im Zuge der Basismessungen für REDUS durchgeführt wurde. Es wird gezeigt, dass die Methode es erlaubt, die Schienenoberfläche mit hoher Genauigkeit darzustellen.

Keywords: laser scanning, railway, accuracy estimation, GNSS device, gang car

1 Introduction

Railway industry is one of the spheres that require reliable survey data. Rails are necessary to be monitored for many reasons. Monitoring should be especially carried out when there are some civil engineering works adjacent to rails. Such works can cause deformations in the rail geometry (Soni et al. 2014).

Traditionally for rail monitoring total stations are used. Total stations observe reflective prism targets attached to sleepers. This method is very accurate but it has some drawbacks that include the necessity of spending much time for prism attachment, installation of total stations; the number of interruptions because of passing trains; prism movements correlating with movements of rails (Soni et al. 2015). Therefore it is necessary to find an alternative method for rail monitoring practically without using reflective prism targets.

Laser scanning can be this alternative method. It is a modern technology in the surveying being applied for large scale topographic mapping, three-dimensional modelling and monitoring of infrastructure objects. Laser scanning allows acquiring 3D coordinates of any object surface more rapidly. It provides a dramatic reduction in costs. The time of field works when applying laser scanning is reduced. Laser scanning captures up to 500,000 points per second with an accuracy of 15 mm or better (Milev and Gruendig 2007).

Laser scanning systems produce large dense data sets which provide detailed geometric information of any observed object. Laser scanning systems are divided into static and kinematic ones. Static systems are mounted on a tripod whereas kinematic ones – on a vehicle (Gonçalves et al. 2012). Scanning by static systems got the name of terrestrial laser scanning (TLS) and scanning by kinematic ones – mobile laser scanning (MLS).

TLS and MLS are non-contact methods. It makes possible to avoid a human impact on an investigated object. Laser scanning data are independent of ambient illumination. It is possible to scan in dark conditions or even at night. TLS and MLS have become widespread in many spheres. The development of computer hardware and software favour the introduction of TLS and MLS (Alkan and Karsidag 2012).

For railway industry TLS and MLS both are being applied. MLS acquires data much faster than TLS. The accuracy of data acquired from MLS is usually lower than the one from TLS. Nevertheless the development of kinematic survey methods has reached a level that allows using them for high precision applications. The accuracy of the MLS data and the TLS one converge (Gräfe 2008). In turn the TLS data accuracy is being improved as well.

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2 Geodetic reference and calibration layout REDUS

The SIEMENS Test & Validation Centre in Wegberg-Wildenrath hosts a set of eight 40 to 60 m high towers with GALILEO pseudolites (railGATE) and REDUS, a rail-based reference and calibration layout for static and kinematic

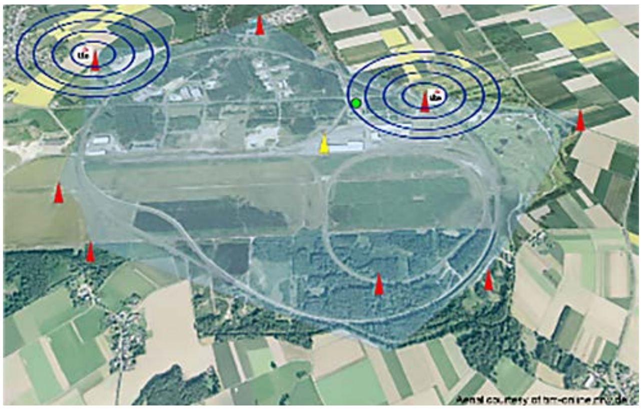


Fig. 1: The railGATE

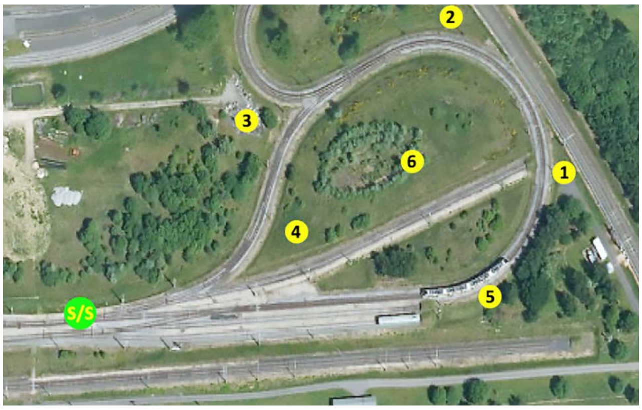


Fig. 2: Reference rail track and positions of pillars

applications. It consists of a railway loop of about 550 m length, a high precision geodetic network represented by six heavy observation pillars (Fig. 2), an electric gang-car for carrying the devices under test (DUT), any sensor and measuring units as well as 54 control (collimation) marks at the rail shaft for the control of the rail movement, on which spherical prisms can be fixed (Pölöskey et al. 2014). The scheme of railGATE is shown in Fig. 1.

All measured data and results are open for the use by any institute or client doing its calibration or test work. REDUS is a set up for the use of Geodetic technology in the rail and automotive industry. The Galileo pseudo signals can be used for research and any development, calibration or testing work. The position of the rails is only quasi – invariant. They move slightly with the temperature and other impacts. Therefore many experiments need the whole bunch of measurements and results over the time to exclude such influences or to take regard of the tendencies.

DUT are mounted on a special platform that is located on the battery powered, self-driving electrical gang car. The gang car moves along the rail reference track. This track has a form of a dedicated loop with a length of about 550 m and a railway siding of about 150 m. The precision of the network is in the sub-millimeter range. The trajectory of the gang car is pursued by a GNSS rover and can be tracked by a total station mounted on any observation pillar. On these pillars any surveying instrument can be mounted to carry out surveying observations concerning the stability of the network and the 3D track analysis, as well as the driving vehicle characteristics (Pölöskey et al. 2014).

For the 3D track analysis by a total station the mentioned special collimation marks are used. They are attached to the inner rail track shaft in a distance of 10 m approximately. The control (collimation) mark is a flat, circular metal with a diameter of about 2 cm, taped on the shaft of the rail. The spherical prism can be attached on that by a magnetic coupler. Control measurements of the reference track position are usually carried out with a total station in different seasons of a year. The results of such control measurements can demonstrate deviations in a track position. All deviations are usually caused by temperature differences in different seasons (Pölöskey et al. 2014).

3 Background

On INTERGEO® 2014 there was designed a memorandum of understanding between the GEOHAUS-Consortium and the Siberian State University of Geosystems and Technologies (SSUGT) about scientific cooperation. The GEOHAUS consortium consists of Fraunhofer IMS Duisburg, Geodetic Institute of the university Bonn, Zenit GmbH Mülheim an der Ruhr, Agit GmbH Aachen, Hansa Luftbild AG Münster, Geosat GmbH and GEOHAUS GBR both Mülheim. As a result of this memorandum, signed in January 2015 in Mülheim an der Ruhr, the first cooperative work has been carried out in August 2015. During two weeks specialists from SSUGT and GEOHAUS worked together in Wegberg-Wildenrath and Mülheim. The whole complex of control work including laser scanning has been performed. One main goal was to use the laser scanning method for rail track position monitoring. The exciting question was, if laser scanning is capable to provide sufficient accuracy for the monitoring and if it can compete with the total station results. For this purpose both laser scanning and total station measurements were carried out. It was planned to cover the collimation marks by the laser scanning modelling of the rail track area.

For monitoring it was decided to apply TLS but not MLS. It was connected with the fact, that the reference network area is not so large and the TLS accuracy is a bit higher than the MLS one. The Leica ScanStation P20 was applied. The ScanStation P20 is a modern high speed scanner that has a measurement accuracy of 3 mm according to its technical characteristics.

4 Results of Laser Scanning

Laser scanning was carried out from several freely chosen scanning positions. These positions were positioned close to the rails and covered the whole reference rail track area. The visibility of the inner rail track and of the collimation marks taped to the rails should have been provided. The laser scanning device was mounted on observation pillars as well.

For further high-accuracy registration of scans and for the transformation into a local coordinate system from each scanning position it was necessary to carry out detailed scanning of special flat targets installed on the pillars. Three or four targets should be visible from each scanning position. For each installation of the laser scanner all targets were rotated to the direction of its installation.

The requirement of visibility of at least three targets was met. The targets as control points allow registering scans with high accuracy (instead of cloud to cloud referencing) and its transformation into the local coordinate system. The accuracy estimation of point cloud transformation is presented in Tab. 1. The coordinates of the pillars were used as control points. The point cloud was transformed in RiScan Pro software.

The registered and oriented point cloud allowed to determine the track gauge. Unlike the total station measurements laser scanning provides scintillating measurements with an incremental distance. This enabled us to vectorise the inner sides of the rails by modelling. To improve the accuracy of the rail vectorization a 3D model of rails was inscribed into the point cloud. Covering areas without or with only a few scanned positions a small noise of the result had to be accepted. A digital elevation model based on the classified point cloud was generated as well. In Fig. 3 the results of the digital elevation model and rail vectorization are presented. In this figure the collimation mark positions are shown in form of black circles as well. The collimation marks were loaded for checking the absolute accuracy of the transformed point cloud. Numbers of all used collimation marks are added. Coordinates of the marks were measured with a total station. In Fig. 4 deviations from 1,000 mm for track gauge measurements are shown for the outer loop contra-clockwise, in Fig. 5 – for the inner rail track from the right to the left. The distance of 1,000 mm is the designed one between inner rail sides called the track gauge. During a year this distance can be changed due to various conditions such as temperature. In Fig. 4 and 5 a zero value means that the track gauge equals 1,000 mm. For example the value of minus 6 means that the track gauge equals 994 mm. Thus, the real changes in the track gauge could reach 10 mm.

In Fig. 6 an example of a collimation mark position with a top view is presented, in Fig. 7 the cross-section belonging to this mark position. The mark position is

Table 1: Accuracy estimation of point cloud transformation into the local coordinate system

Pillar number	X [m]	Y [m]	Z [m]
1	0.0010	0.0010	−0.0006
2	0.0002	−0.0002	0.0013
3	−0.0001	0.0010	−0.0012
4	−0.0021	−0.0004	0.0013
5	0.0006	−0.0007	0.0012
6	−0.0004	−0.0008	−0.0015

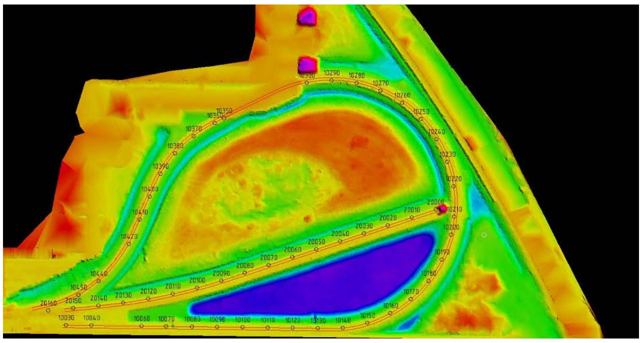
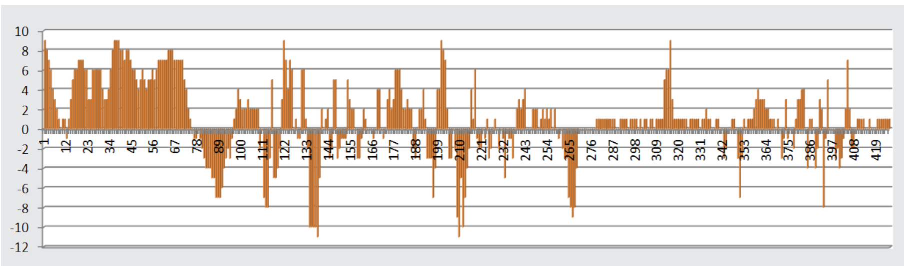
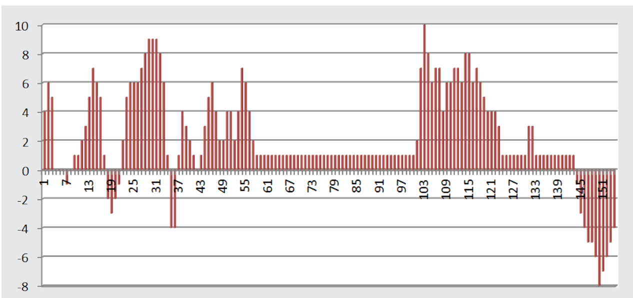


Fig. 3: Reference rail track and positions of pillars





↑ **Fig. 4: Track gauge for the outer loop**

← **Fig. 5: Track gauge for the inner rail track**

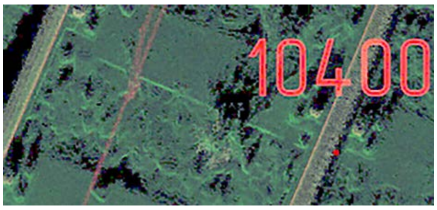


Fig. 6: Example of a collimation mark position with a top view

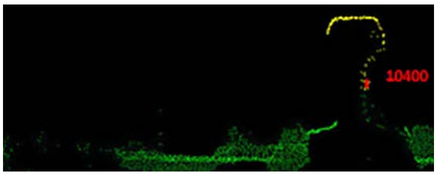


Fig. 7: Example of a collimation mark position with a side view

shown without application of correction for mark constant. Places with missing laser scanning data are to be found at (276 … 309 or 61 … 97), where there was no scanning position. The 3D model of rails bridge over all such places. To avoid a problem of missing data it is recommended to scan from left and from right side of a rail track. In this example the rail track was scanned only from one side.

3D distances between the corrected collimation mark positions and rails have been measured. Tab. 2 illustrates the absolute accuracy estimation of point cloud registration. The accuracy obtained between the corrected collimation mark positions and rails is essentially lower than the one for point cloud transformation into the local coordinate system based on the pillar coordinates. It is connected with the fact that the pillars are control points and collimation marks are check points. The control point accuracy is always higher than the check point one.

Tab. 2: Absolute accuracy estimation of point cloud registration

	3D distance [m]
Mean error	±0.0033
RMS error	±0.0020
Maximum error	±0.0313

The results shown in Tab. 2 prove that a TLS point cloud can be used for rail monitoring. It means that the rail track position can be determined even without collimation mark attachment to rails and their coordinate measurements. TLS data of rail track are a highly accurate base for testing any GNSS receivers and positional sensors.

5 Conclusion

During the cooperation between the SSUGT and the GEOHAUS-Consortium a set of surveying works for testing GNSS receivers and positional sensors has been done. These works produced highly precise local coordinates, additionally embedded into the overall German network. The important part of the work was a monitoring of the rail track located within this network. For the first time it was decided to apply TLS for the monitoring in this area.

As a result of the work it was revealed that laser scanning is capable to provide high accuracy for rail track monitoring. Due to large and dense data sets laser scanning can extract detailed geometric surface information of any objects located around the area. It was proved that laser scanning is a method that can replace the use of collimation mark coordinate measurements with a total station. The necessary condition for this opportunity is to scan from both sides of a rail track, to use special targets for registration of scans as control points and modern high accuracy models of laser scanners. The study was carried out with one of such scanner – Leica ScanStation P20.

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