Solving Problems of Railway Safety and Maintenance with Laser Scanning Systems

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INTRODUCTION

When using 3D imaging, it can be tempting to solve a technical problem with the most advanced scanning system available. But high density point clouds aren't always the best solution for clients. Take, for example, the use of laser scanning in railway safety.

Railways require preventative diagnostic assessments to ensure that erosion or other environmental changes haven't made the tracks unsafe. The structure gauges, distance between tracks, track bed stability, and ballast bed profile must be measured for the entire length of a track. Such a task requires rapid data gathering, rapid analysis, and a quick response. Alexander Bakhrakh, of the company INFOTRANS, explains several approaches to railway infrastructure diagnostics. Through these examples, he shows which scanning technology best fits the range of problems found on railways, and why strategic scanning, along with smart processing methods, can create efficient diagnostics without relying on expensive scanners to create high-density point clouds.

PROBLEMS ON RAILWAYS

Every railroad has problems. Trains go off the rails. Railway lines collapse. At the very least, these problems result in money losses and delays. Problems, of course, can also cause immeasurable human losses.

Some recent examples of accidents include a derailment in Switzerland, Colorado in the United States, and in Russia. The general reason for all these problems is that the railway track was not in the safe, correct condition.
Problems on Railway

Figure 1

Four common conditions can cause problems with tracks: an incorrect condition of track geometry, an incorrect relation of gauges, instability of subgrades, and instability of ballast. Determining incorrect track geometry has been automated for a long time, and is generally considered a solved problem. Where once it was measured in a time-consuming way, now super-modern cars with laser scanners and computers for displaying information measure track geometry.

But the remaining three problems for tracks – gauges, subgrades and ballast – are generally solved with manual methods in Russia, and elsewhere. The disadvantages of this are clear: a prolonged measurement step and an overall time-consuming process.

The reasons: incorrect state of track parts

Figure 2
To solve these problems automatically, the INFOTRANS company has designed a spatial scanning system based on laser scanning. This system is a part of a multifunctional measuring complex, called ERA. A few basic requirements are needed to make this system work: automatic recognition of violation of structure gauges, the automatic recognition of unstable subgrades and the automatic recognition of unstable ballast beds.

**GAUGE RELATIONS AND POSITIONS**

One cause of train crashes and delays is problems with gauges. Namely, if any object is so close to a track that a train will hit it. Or, if two adjacent tracks are so close that two trains can collide. Each country has standards for a clearance outline to avoid such problems. To ensure that the tracks are adhering to the outlines, one can use measuring systems that measure 3D data points. These measurements need to be related with the running surface of the track, and the vertical centerline.

![Point Clouds](image)

*Figure 3*
As one can see from a few example point clouds, there is a difference between the absolute coordinate system and the so-called the track coordinate system, which is the coordinate system as it relates to the running surface and track centerline. In this system, one can directly say if something violates gauge guidelines by taking the point coordinates. If the measured point is in sight, this area violates the gauge. It’s simple, and it can be measured with accuracy.

**Track Coordinate System**

**Measurement points requirements**
- Accuracy: 2 cm
- Step across: 2 cm
- Range: up to 3 m
- Real-time response on violation

*Figure 4*

Another important requirement in infrastructure diagnostics is to have a real-time response to critical violations of gauge guidelines. A difficult step to achieve this is to find a way to measure the adjacent track center and the distance between tracks. But this can be done with an algorithm.

The algorithm incorporates a model scanning principle—the scanner is set to measure distances from one center point at given angles. But the required measurements are not the most stringent, just 15 points on the track for a scan to recognize adjacent tracks with such an algorithm. Which means a relatively low-resolution scanner – just a 1 degree resolution scanner – can do the job.
With this approach, a train car can use just a scanning system and doesn’t need an IMU (Inertial Measurement Unit) to solve the problem.

**SUBGRADE STABILITY**

Subgrade instability, which could be caused by a landslide, is another known cause of railway accidents. One advantage of using scanner data to catch subgrade instability is that the system can recognize the position of the track without an IMU.

![Subgrade Profile Recognition](image)

**Figure 5**

The system does need to measure the profile of the subgrade or calculate its slope. An algorithm that uses measured points recognizes good data points and goes through a filtering process will eventually produce a final, smooth subgrade profile. However, one limitation is that the system cannot recognize objects on the subgrade that are longer than 10m.
BALLAST STABILITY

Subgrade profiles are also useful in assessing another source of train crashes – ballast instability. Safe railways need to have sufficient length of side parts, called shoulders, and also an important parameter is ballast level. If it’s not sufficient, it won’t hold the track. The ballast bed needs to be no more than 260mm under the running surface.

SCANNING SOLUTIONS

A scanning system that addresses each of these rail safety parameters can be relatively low-cost. In this case, the camera mounting features three scanners with a resolution of IP 67. Although the scanners do not have to be high resolution, they need to be mounted with good protection considering the rough environment and weather conditions experienced by trains in Russia.
Mounting features

- 3 scanners SICK LMS
- Low price, low resolution, IP 67
- Vertical orientation of scanning plane

Figure 7

They are set at an orientation to scan a vertical plane. With this set up, the scanners can measure data at speeds up to 120 kph, and detect objects along the track at least 30 cm in length, or longer. The scanner will continue to measure properly with a maximum embankment height no greater than 13m, and as long as the train's tracks or any adjacent tracts aren't covered with ballast. Current scanning systems with this set up can run for a distance of 2,000km every day they're measuring and operating.

The main goal of laser scanning the railways is not just to measure values, but also to inform operators, track maintenance staff and traffic controllers about any and all violations found. So, an operator's workstation is set up and linked to each scanner car with software. This way, the operator can see all signals that are measured along with signals from other systems in real time. More information can be gathered in statistics during post-processing.
A ballast stability violation, for example, could be easily visualized relative to the train and in readable tables. Every parameter is calculated automatically while the system is running, and clients can receive a complete report for all violations within a stretch of railway.

**Software: Ballast Stability Violation**
COMPARATIVE TESTS: SCANNER VS SCANNER

It's always important to look for ways to improve your system’s quality, and in doing so our team decided to test our scanning system against a high-performance, high-resolution scanner.

Data of one railway section was gathered with the system from INFOTRANS – namely, ERA – and compared to data of the same section gathered by a high-performance, high-resolution system – namely Lynx.

The point clouds of the high-performance system contained much more detail. Yet, both systems were accurate enough to meet safety assessment parameters, while the high-performance system cost 10 times the price.

So while there is always an opportunity for improvement, the next step may not be to incorporate a high-performance scanner.

THE GOAL: TRACK SAFETY, NOT POINT CLOUDS

If the goal is to improve the accuracy, then this could be done by making a comprehensive approach to the assessment of railway safety.
Additional information for this approach need not be found with laser-scanning. For example, a video surveillance system could aid in the automatic recognition of rail movement, the automatic recognition of existing welding joints and bolting joints as well as recognition of defects on the roll surface of the tracks.

**Track Surveillance System**

*Automatic recognition of:*
- Light notes and definition of the amount of rail movement
- Bolted joints and definition of the amount of gap
- Welding joints
- Defects on the roll surface and determination of their size

*Figure 11*

The system can further be improved with the automatic inspection of rail heads and their wear and tear, among other parameters.

**CONCLUSION**

Integrating scanning technology into rail cars can help prevent some the most dangerous problems in railway safety and maintenance. A well-equipped car with scanners aimed in a vertical plan can log obstructions, uneven slopes and other potential risks while notifying railway workers in real time.

Although, a comparison of laser scanners found that high-resolution scanners produced richer, more accurate point clouds (as expected), the extra data did not significantly change the safety performance...
of the scanner cars. Rather, video surveillance systems and smart algorithms could do more to improve railway infrastructure diagnostics at a much lower cost.

**BIOGRAPHY**

Alexander Bakhrakh is the principal researcher for spatial scanning system and rail area video surveillance system projects at the company INFOTRANS. His research focuses on scanning and video data processing with mathematical modeling. Prior to joining INFOTRANS, Bakhrakh studied math and informatics at Samara University in Samara, Russia.