Agile Multi-Sensor Platform LEONARDO: Evaluation of new Monitoring Technologies in an Operational Environment

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Abstract. Integrating new rail infrastructure measurement techniques requires a deep understanding of data and monitoring goals. The LEONARDO platform facilitates rapid testing of technologies, providing easy access to operational data for collaboration with industry and research partners. The platform focuses on acquiring data from infrastructure assets from on-track perspective within a ± 5-meter radius, aiming to gather valuable information, including the possibility of detecting underground problems. Practical examples showcase that applications are working and are more than a one of test: this is due to the involvement of end-users and their persistence to use the information. The diverse data sources pose also intriguing challenges for in-depth research, making this setup appealing to researchers. Crucial to its success is the unobstructed access to operational infrastructure.

Keywords: railway infrastructure; digitalisation; data-based diagnostics; monitoring platform.

1 Introduction

Implementing new rail measurement techniques is complex and time-consuming. Understanding data in line with monitoring goals is crucial. The LEONARDO platform swiftly incorporates and tests emerging technologies, providing the ability to combine the data of all technologies onboard.

Repurposing an old tamping machine and incorporating various measurement systems such as Lidar and ground-penetrating radar can result in a valuable testing platform. Collaborating with end-users involved in maintenance and renewal projects, as well as researchers, fosters a dynamic environment instrumental for exploring novel practical applications and deployment [1].

Section 2 elaborates on the platform and its current technologies, Section 3 delves into recently integrated technologies, discussing their selection criteria and applications in addressing various rail infrastructure challenges. Finally, Section 4 outlines initial results and provides a glimpse into future development steps.

2 LEONARDO platform and available technologies

Strukton developed the "LEONARDO" platform, an agile measurement vehicle, to improve rail infrastructure understanding amidst increased competition, stringent maintenance contracts, elevated safety standards, higher train traffic, and a shortage of technical expertise. The platform's focus was on collecting extensive digital track data during a single trip and integrating it with other digital data for comprehensive remote analysis, utilizing a blend of established and emerging technologies.

2.1 Scope of the platform

The scope covers data acquisition, particularly for assets along the railway line within a range of 360 degrees and approximately 5 meters around each asset (cf. Figure 1). The goal is to gain valuable information, potentially even observing underground issues.

The platform is equipped with the "TRACKSCAN" laser measurement system to measure railway tracks and a Lidar sensor to map the track surroundings. Additionally, the "GEOCONDA" optical camera system captures detailed visual information of both the railway tracks and their surroundings.

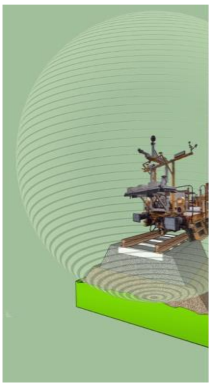

Figure 1: Scope rail infrastructure monitoring, range of 360 degrees

The LEONARDO (cf. Figure 2) also incorporates 3D ground radar to measure ballast and ground layers, providing valuable data regarding the stability and consistency of the rail infrastructure. Additionally, axle-mounted acceleration sensors are integrated to record vibration patterns, aiding in the assessment of overall rail performance and safety.

With these combined sensor technologies, comprehensive and accurate data on both the rail condition and the environment can be gathered.

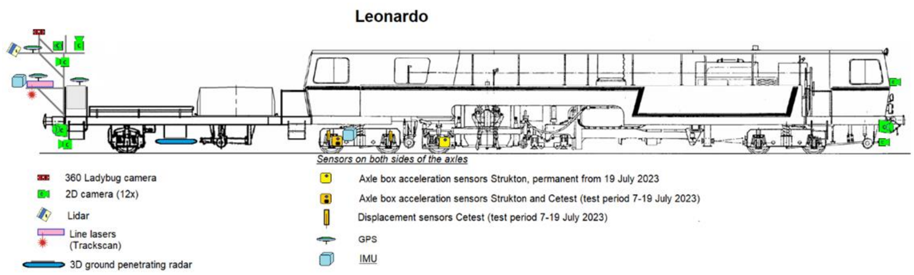

Figure 2: The LEONARDO platform

Specific objectives have been outlined to facilitate the generation of readily accessible digital data within an organization tasked with daily maintenance and renewal projects, initiating the LEONARDO concept. Three goals have been formulated for this:

a) Digitally capture as much rail infrastructure data as possible in one trip.
b) Process this data and enrich it with other available digital (process) data;
c) So that the user can do his work from behind a computer based on current track information

The platform, to be a valuable tool, had set general requirements. These include operation between trains (90km/h) on Dutch tracks day and night with a 5m coverage, accuracy in GPS-based location (+/- 20mm), precise measurements for PVR (<1mm) and PVS (<10mm), suitability in typical Dutch weather, operation in a temperature range of -10 to 40°C, compatibility with standard PC software, seamless data streaming, and proper linkage of the data with location, date, and time.

2.2 Implemented technologies

The Leonardo platform integrates Geoconda video, Lidar, and Trackscan systems. The Geoconda video system has 360-degree and flat image cameras capturing images from "Leonardo front" or "Leonardo back" viewpoints based on travel direction. In 2021, Lidar (Velodyne), a 360-degree camera (Flir Ladybug), and an Applanix POS LV box were integrated into Leonardo.

Velodyne's Lidar generates point clouds, Ladybug captures 360-degree photos, and Applanix box records GPS positions. The calibrated Lidar system can be easily mounted within 5 minutes using a sled construction. Trackscan, part of the Strukton Network Scan, assesses overhead wire and track condition. It offers flexible data acquisition suitable for various network scales, excelling in challenging areas like urban tram/metro networks or network hotspots. Installation on different hi-rail vehicles allows section measurements on regular roads, adapting to specific requirements (cf. Figure 3).

Integrating Trackscan, cameras, and Lidar has advanced significantly. Coordination is improved through synchronized measurement targets on Applanix boxes. Adding more systems to the vehicle is effortless, focusing on accurately recording their orientation in relation to existing targets, making them central components of the setup.

Figure 3: (L) Measuring equipment on a lorry and (R) the LEONARDO

3 Recently implemented technologies

3.1 Ground Penetrating Radar

The original goal for the LEONARDO platform was to comprehensively survey a 5-meter radius around the measurement train (cf. Figure 1). The recent integration of advanced 3D ground-penetrating radar (GPR) technology has significantly enhanced detection accuracy.

Key advancements in GPR technology include higher resolution through increased grid density and step frequency, refined signal processing to reduce noise and improve object detection clarity, expanded depth range for effective detection of underground anomalies and irregularities. Additionally, 3D imaging improves spatial object understanding, and automation coupled with AI expedites detection processes, enhancing overall reliability.

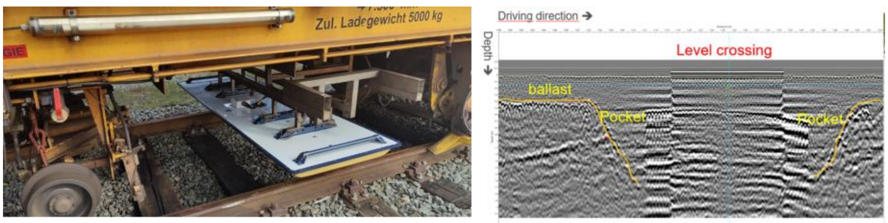

Figure 4: 3D GPR antenna and (R) ballast pockets found on each site of a level crossing

GPR accuracy is affected by ground and environmental factors, making it applicable across various domains, such as inspections, track maintenance support, and renovation tasks. GPR provides detailed data at different depths, offering valuable insights with radar penetration depth varying by soil type. Its applicability at track speed aligns with operational needs. Notable potential applications of Ground Penetrating Radar (GPR) include visualizing ballast pockets for rail maintenance, detecting track alignment issues, identifying ballast layer depths, locating badger setts, and potentially uncovering historical explosives. Figure 4 shows the 3D GPR antenna mounted on the Leonardo and located ballast pockets at a level crossing.

3.2 Axle Box Accelerometers

Measuring train axle accelerations isn't a new concept, with active research in this area. It's commonly used to replace costlier track geometry measurement systems and monitor rail wheel contact. These measurements, taken close to the rail contact point, can detect factors influencing rail contact response, like rail imperfections or crossings. While data collection is simple and cost-effective, extracting meaningful insights remains complex.

Incorporating this into the measurement platform offers two advantages: 1) The platform's inspection-grade equipment enhances the development of independent ABA applications by enabling simultaneous data collection. 2) Combining measurement results, even from other inspection-grade equipment, can likely improve data analysis, making this integration a valuable step forward.

We have tested two different types of sensors: The DC and AC (500-5000hz) sensors are mounted on both axle boxes of an unpropelled axle (cf. Figure 5).

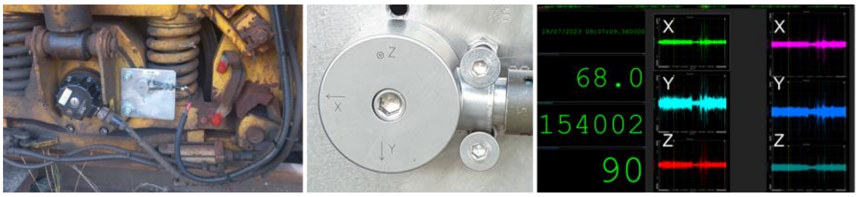

Figure 5: Acceleration sensor (500-5000hz) mounted on axle box

4 initial results and future developments

The use of the LEONARD proofs to be good for several practical applications. In this section we present some of these, such as: finding causes for anomalies in the track and creating track layouts.

4.1 Causes anomalies in the track

First analysis shows that it seems possible to use ABA data to detect anomalies in the track. Based on their locations we found possible causes in the video- and the Trackscan data. Figure 6 shows two types of anomalies found in Leonardo track data by using of the ABA data for detection. This can help to quickly find hotspots in the tracks that needs other maintenance than standard used.

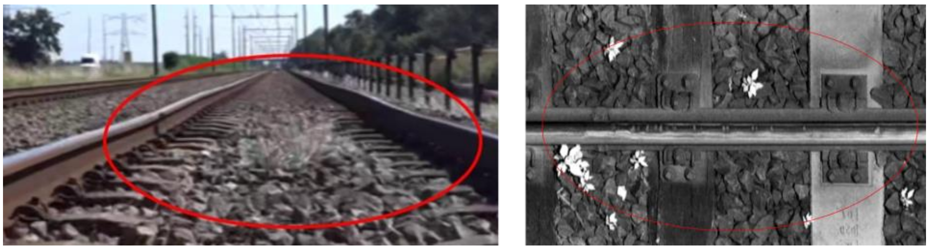

Figure 6: (L) a negative thermite weld and (R) corrugated rail

4.2 Track Layout Design

Effective track layout designs necessitate precise information about various track components like rail type, welds, joints, sleepers, and fasteners. This involves extensive fieldwork and manual processing of collected data. During field inspections, components are visually identified, and their approximate locations are recorded using a GPS rover set. The results of object detections from track scans are accurately positioned, and a transformation pipeline converts them into CAD drawings. In the example, rail position and profile type, welds, joints, sleeper types, and fasteners are detected and represented accordingly. The use of a commercial ETL (Extract, Transform, Load) tool streamlines the conversion of track scan results into CAD drawings (cf. Figure 7).

Figure 7: Trackscan results directly into a CAD drawing

4.3 3D-modelling underground infrastructure: pipes & cables

Like the aforementioned practical use (see 4.2), we recognize the potential of utilising the data to create an image of the underground infrastructure. In the context of implementing systems like ERTMS and positioning balises, an accurate representation of the current infrastructure is crucial. This involves a digital representation of both above-ground and underground reality (cf. Figure 8). This up-to-date digital representation is then linked to current data regarding rail objects, as accessible in underlying databases.

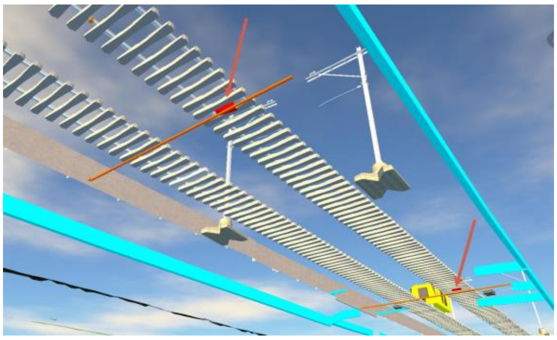

Figure 8: example of visualisation of the underground infrastructure

5 Conclusion

Our experience shows that easy access to real-world operations is very important. This access helps in two main ways: it lets us quickly use practical monitoring data in different ways and provides essential data for research. The LEONARDO platform takes the needs of both people who work with the system and researchers seriously, treating them as important users. Being able to access the real-world operational setup is incredibly useful for these users. It helps in situations like fixing errors, calibrating equipment, or testing new tools. Also, it allows for useful comparisons with other tools to improve their performance and reliability, such as comparing different ABA technologies to use in active train services, for instance.

Acknowledgements

Co-funded by the European Union

This work has received funding from the European Union via the Europe's Rail Joint Undertaking under Grant Agreement No. 101101966. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Europe's Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them.

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