HUMAN-ASSISTED REAL-TIME MONITORING OF INFRASTRUCTURE AND OBSTACLES BY REGULAR RAILWAY TRAINS

1. Understanding the challenges of railway infrastructure maintenance

Ever since the first railways and their respective track systems came into existence, there is the necessity to maintain their infrastructure to ensure early detection of problems to arrange suitable maintenance activities and avoid accidents and operational constraints. Reasons for infrastructure problems can arise due to wear and tear or deterioration over time or they can result from external factors such as climactic exposure or intentional damage.

As trains run on predetermined tracks and cannot swerve, the importance of intact and unhindered rail connections becomes apparent. Many problems that appear in practice, for example a broken track or a loose object on the track bed, require a prompt detection and a quick rectification to avoid damages, and to further prevent downtime and loss of revenue, as well as potential fatalities of passengers and maintenance workers.

Track anomalies


Fracture


Damage


Vegetation


Foreign Object

Experts estimate yearly maintenance costs of about €50,000[1] per km and assume that a decrease of 15–55% can be achieved through improved maintenance.

There are two current state-of-the-art methods for railway infrastructure monitoring:[2]

1. Continuous superficial on-site monitoring by trained personnel
2. More thorough examination via measuring vehicles

1 C. Esveld and C. Esveld, Modern railway track, Second., vol. 385. MRT-productions Zaltbommel, Netherlands, 2001
2 S. Jovanović, D. Božović, and M. Tomičić-Torlaković, "Railway infrastructure condition-monitoring and analysis as a basis for maintenance management," Građevinar, vol. 66, no. 04., pp. 347–358, 2014.

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Manual on-site inspections are still the most common method, even though they can no longer be conducted daily. Unfortunately, these inspection works put the lives of employees in danger, therefore accidents and fatalities happen frequently while performing these activities.

The Austrian Federal Railways (ÖBB), for example, use so-called Rail Checkers – vehicles equipped with specialized and high-precision measurement systems. Due to the high acquisition costs of such vehicles, the availability is limited. They must inspect the entire railway network in various intervals, ranging from a few weeks to up to a year depending on the respective rail section. A measuring vehicle running only every 12-52 weeks renders an early problem detection virtually impossible.

To respond to these challenges, our strategy is a combination of a more frequent superficial with a precise but intermittent method to increase the chance of detecting severe problems in between cycles of routine monitoring early on, and to detect and predict problems before they even arise.

The HARMONY system is an intelligent processing of the data collected by a modular, cost-efficient, adaptive, and retrofittable on-board system equipped with adequate sensors. This system enables remote monitoring of the rail infrastructure by a human operator (remote analyst) to support decision making, as well as provision of an accurate and automatically acquired condition documentation of the railway infrastructure.

2. Measurement vehicle versus on-board system

Railway companies have been using measuring vehicles with precise measurement systems for decades.

With these systems

- track geometry
- curvature, twist, and elevation of rail tracks
- deviations on sleepers
- clearance outline
- overhead wiring
- wear and tear

and other parts of the rail infrastructure are measured with high precision.

To ensure high safety standards, these measurements are essential for long term maintenance. Due to the high cost and the effort needed to conduct these maintenance works, infrastructure providers only possess a limited number of these vehicles and can therefore only cover a limited amount of mileage of their rail network per day.

Additionally, these measurements might disrupt the operational schedule, especially on high-speed routes due to the limited speed of these vehicles.

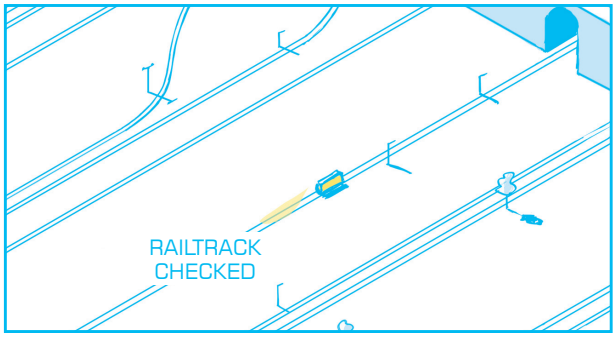

Figure 1: Cost-intensive measuring vehicles can only cover a limited amount of the rail network per day

To combat these challenges, a simple and quick infrastructure check with a system that can be retrofitted on regular passenger or freight trains is a perfect match to add short time and recurrent inspections to the scheduled long-term maintenance as described above.

Such a device can automatically detect numerous anomalies, such as:

- broken sleepers
- cracks and other anomalies on the track and on switches
- loose screws
- foreign objects and animals on the track
- clearance restrictions because of unwanted vegetation

The main benefit of an intelligent on-board device is that anomalies are reported upon detection without any human interaction. Evidence of the irregularity, such as images or short video sequences, and localization information are sent to a control center. A remote analyst decides on further measures to be taken on the given anomaly before further damage can occur.

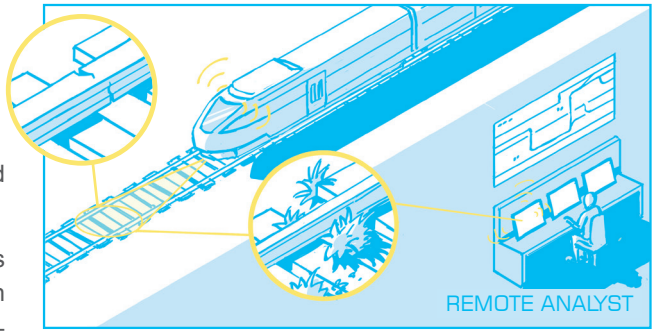

Figure 2: Automatic detection of rail infrastructure anomalies and alerting of the remote analyst

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3. Mission Embedded Solution

HARMONY is an intelligent on-board monitoring system mountable on regular trains to support the operator's staff in decision making of acute maintenance work and prevent potential consequential operational constraints.

The solution provides suitable data analysis tools, sensor correlation methods, data interpretation and synchronization methods that considers economic constraints and high demands on robustness, performance, and dependability. The intelligent on-board pre-processing algorithms provide smart methods to reduce the huge amounts of sensor data prior to transmission to the control center, avoiding the necessity of having to transfer raw data.

The precondition for such methods is the robust synchronization and correlation of data from multiple sensors to gain reliable information on anomalies. Additionally, reliable localization information fused from different methods allow precise and reproducible allocation of the findings.

Key characteristics of our solution

The main aspects of the system can be categorized and summarized in the following points:

- Real-time data processing on board:
  - Scanning of the rail infrastructure using state-of-the-art and cost-effective sensors
  - Highly accurate geo-tagging of the measured sensor values based on reliable localization methods
  - Synchronization, pre-processing, fusion, and reduction of sensor data to detect anomalies using innovative AI algorithms
  - Continuous automatic detection and recording of various track infrastructure anomalies using AI
- AI Backend Processing:
  - AI-based data aggregation of sensor data collected on multiple trains to perform time series analysis for optimized maintenance operation
- UI/UX Frontend Design:
  - Optimized human-machine interface for the remote analyst

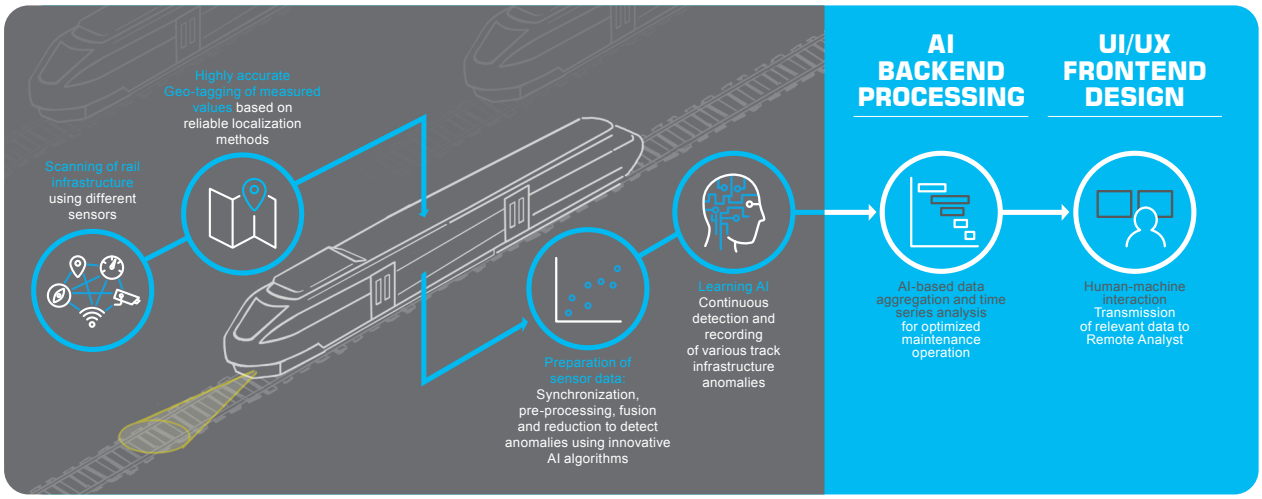

Figure 3: Holistic and intelligent on-board system to combat rail infrastructure problems

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4. Proven benefits of Mission Embedded On-board System

The HARMONY system is universal and versatile, and can therefore be easily extended to be deployed in other applications, for example:

- Multi-sensor system for autonomous (railway) vehicles: System with an intelligent algorithm will autonomously detect obstacles and collisions in order to alleviate the decision-making for the remote analyst to resolve anomalies and initiate course of action.
- Autonomous crane: Autonomous loading/unloading routine of cranes where a remote analyst has to resolve ambiguous and/or critical situations

This list is non-exhaustive and can easily be extended to other industries.

The system provides an excellent cost-benefit ratio, with the costs efficiency arising from the low sensor costs, allowing numerous rail vehicles to be equipped with our system to reach a high-frequency monitoring covering the entire railway network. The low asset costs further allow any railway operator to readily scale up with a growing railway network.

Summary of the Benefits

To summarize, the benefits for railway and rail infrastructure operators are multifaceted and can be described by the following key points:

1. Cost-efficient on-board system facilitates high-frequency and almost continuous monitoring
2. Intelligent on-board pre-processing to decrease the required bandwidth for data transmission
3. Reliable and robust algorithms based on AI for pattern detection and anomaly recognition in fused data by multiple sensors from multiple data sources (railways)
4. Safer and more reliable railway infrastructure due to early recognition and prediction of possible problems
5. Drastic decrease of repair costs by early detection of possible defects
6. Reduction of manual inspection work and increase of occupational safety

5. Closing remarks

Mission Embedded has become a pioneer for intelligent sensor systems in railroad applications. Nearly 1000 sold driver assistance systems for the railroad market prove the expertise and know-how in this field. The application of machine learning and artificial intelligence in various safety critical use cases have led to several pending patents in the relevant field.

Mission Embedded is the partner for your product innovation:

- **100 % Cost Security**

  We guarantee development and series prices right from the start, keeping you in control of your product innovation costs and drastically minimizing your risk. This allows you to focus on your market, while we take care of the technology and implementation.

- **25 Years Investment Protection**

  We offer up to 25 years of long-term support and lifecycle management. To ensure this, we rely on many years of life-cycle experience and intelligent, forward-looking strategies. Even long after market launch, we provide support for maintenance issues, production customizations, and issues in the field.

- **Know-How Advantage from 50+ Experts**

  Real added value is created through a combination of experience and knowledge. We ensure your lead in product innovation with the experience and specific know-how of our highly specialized experts in the core areas of image and sensor processing, sensor and system integration, artificial intelligence, reliability, safety and security, radio and communication, embedded systems, low power systems, and approvals.

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