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Automating track inspection through using instrumented hi-rail truck

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Is this a:____ Full paper? _×___Short paper?

Innovation and Emerging Technologies in Railway.

ABSTRACT

Utilizing inspection technologies has demonstrated efficacy in monitoring railway tracks and enhancing the overall safety of railway operations. The introduction of automated track geometry measurement systems and their consequential impact on reducing geometry-related derailments underscores the significance of technological adaptation in the railway sector. Maintaining safe track conditions under future climate projections requires more frequent inspections, and consequently track down time. However, the growing demand for rail transportation and supply chain constraints require railway operators to increase the number of trains along their network, consequently limiting the time available for comprehensive track inspection. In response to this multifaceted challenge, railways are actively exploring emerging technologies and embracing automation to facilitate more frequent inspections, thereby enhancing operational efficiencies while upholding safety standards. Addressing this imperative, the National Research Council of Canada (NRC) has undertaken the development of a prototype instrumented hi-rail truck designed to automate select track inspection activities currently reliant on human visual inspections. Equipped with an array of sensors featuring diverse sensing modalities and a range of perspectives, this instrumented truck generates digital representations of the track and its surrounding environment. The resulting digital models, in conjunction with artificial intelligence algorithms, enable the spatial and temporal identification of certain track issues. This short paper provides an overview of the NRC's instrumented hi-rail truck, including both the software and hardware components, the opportunities it presents to supplement/replace specific aspects of visual inspections, and some results from its deployment under actual field conditions.

1 INTRODUCTION

Railway companies strive to employ diverse measurement technologies for track inspection to ensure a safe operating condition for trains. Despite the widespread adoption of advanced technologies, visual inspection of the track remains a regulatory imperative. The frequency of these visual inspections varies, ranging from one per month to two per week, depending on factors such as track classification and annual tonnage, as outlined in existing regulations (Transport Canada, 2021a).

The visual inspection process faces several challenges, making it labor-intensive, tedious, and prone to errors influenced by human factors. This is primarily attributed to the subjective nature of human evaluation and manual record-keeping, compromising the consistency of the identification of potential problems. Additionally, the existing process lacks the capability to quantify and monitor the progression of issues, hindering proactive identification. The prolonged track downtime demanded by the present inspection procedures adversely impacts train schedules, leading to decreased efficiency in railway operations. Furthermore, the current inspection process may prove inadequate in coping with the anticipated increase in weather-related issues under future climatic conditions. Addressing these limitations is crucial for enhancing the overall effectiveness, safety, and adaptability of the railway inspection procedures.

Recent advancements in perception technologies, both hardware and software elements, have introduced new opportunities for enhancing track inspection procedures. The accessibility of high-resolution sensors with various sensing modalities, along with the affordability of powerful on-board computers for real-time data processing on mobile platforms, has significantly transformed the landscape. This technological progress has opened new avenues for improving the efficiency and accuracy of track inspection processes. The deployment of these advanced sensors, along with robust computing capabilities, holds the potential to revolutionize the way railway tracks are monitored, offering a more cost-effective approach to ensure safety and performance in rail operations.

Since 2019, NRC has been actively working on the development of an instrumented hi-rail truck tailored to augment traditional visual inspections (Roghani et al., 2022a and b, Arroyo Mora et al., 2023). This endeavor

involves a comprehensive exploration of optimal hardware solutions and the development of requisite software and algorithms for efficient data processing. This short paper provides a brief overview of the ongoing progress in implementing the instrumented hi-rail truck and its potential contributions to track inspection methodologies. The discussion will touch upon the key aspects of hardware selection, software development, and algorithmic advancements.

2 INSTRUMENTED HI RAIL TRUCK

NRC's hi-rail truck (Figure 1) is instrumented with a suite of sensors and auxiliary components to develop a complete data acquisition (DAQ) system that can acquire environmental data in different sensing modalities and multispectral bandwidths.

The DAQ system is comprised of two units that are located on the roof and on the back of the truck. The system on the roof features one LiDAR, two RGB cameras, and two Infrared cameras, capturing images from each side of the track; while the system on the back features one LiDAR and one downward camera which provides a view of the track. The DAQ also includes IMU, GNSS, and CAN-bus. In addition to these sensors, two high-capacity computers are deployed inside the hi-rail truck to host the supporting software and to facilitate the data acquisition task.

Figure 1. NRC's instrumented hi-rail truck

Except for the IMU, all other sensors installed on the hi-rail truck operate on electromagnetic signals from different spectra (radio waves, visible light, and infrared light). The LiDAR, RGB cameras and infrared cameras provide raw data that could be processed to monitor various features on track or within the right-of-way, and the IMU and the GNSS receivers are used to determine local and positioning information for the other sensor streams.

A software stack hosted on the in-vehicle computer and based on the Robot Operating System (ROS) was developed to facilitate data acquisition and real-time visualization. It includes vendor-supplied and custom drivers to translate binary sensor data into ROS messages. It also included nodes that captured these published ROS messages to save to the local storage of the computer in ROSBAG format for each message. The recorded data in the ROSBAG format can be replayed with accurate time deltas to provide a convenient pipeline for rapid prototyping of data processing algorithms. This provides an opportunity for track engineers to view data later as if they are inspecting the track from a hi-rail truck in the field.

The data processing tasks are very resource intensive and involve the following steps: (1) reading binary files from local/cloud storage, (2) de-serializing the binary sensor data into appropriate formats, and (3) evaluating perception algorithms on the formatted data, etc. All these steps require high GPU, CPU and memory resources. The large volume of acquired data poses a challenge for processing using the available computing capacities.

3 RESULTS AND DISUSSION

The NRC has been proactively engaged in advancing the capabilities of the instrumented hi-rail truck, exploring novel applications. The truck has exhibited successful applications in mapping surface water area and elevation within the track right-of-way (ROW). This capability enhances the truck's utility by providing valuable insights into the water dynamics along the railway tracks. Furthermore, the instrumented hi-rail truck has demonstrated effectiveness in mapping vegetation along a railway line. This application contributes to the overall monitoring and maintenance strategy by offering detailed information about the vegetation profile within the track ROW.

3.1 Mapping surface water area

Water levels in close proximity to railway tracks have a significant impact on train safety. With the anticipated rise in both the frequency and severity of extreme weather events due to climate change, there is an urgent need to bolster the resilience of transportation infrastructure, particularly railways. In response to this expectation, the NRC has explored the potential use of its instrumented hi-rail truck for advanced water detection and inspection near railway tracks.

The system underwent testing on two Canadian railroads to evaluate its proficiency in mapping surface water areas and elevation within the ROW. Utilizing

images from both infrared and RGB cameras, an algorithm was trained to autonomously identify the presence of water within the ROW. Subsequently, a Structure from Motion (SfM) procedure was employed to ascertain the elevation difference between the water surface and the track. This approach facilitates the detection of changes in water elevation over time, providing valuable information for track inspectors as an early indicator of potential issues.

Figure 2a and b show how the surface water at the outlet of a culvert appears in infrared and RGB images taken from the hi-rail truck. Using images from RGB cameras, a 3D point cloud of the scene is generated using SfM techniques. Figure 2d shows a different view for the same area, including the track segment, illustrating how the elevation difference can be measured between water surface and a reference point, such as top of rail.

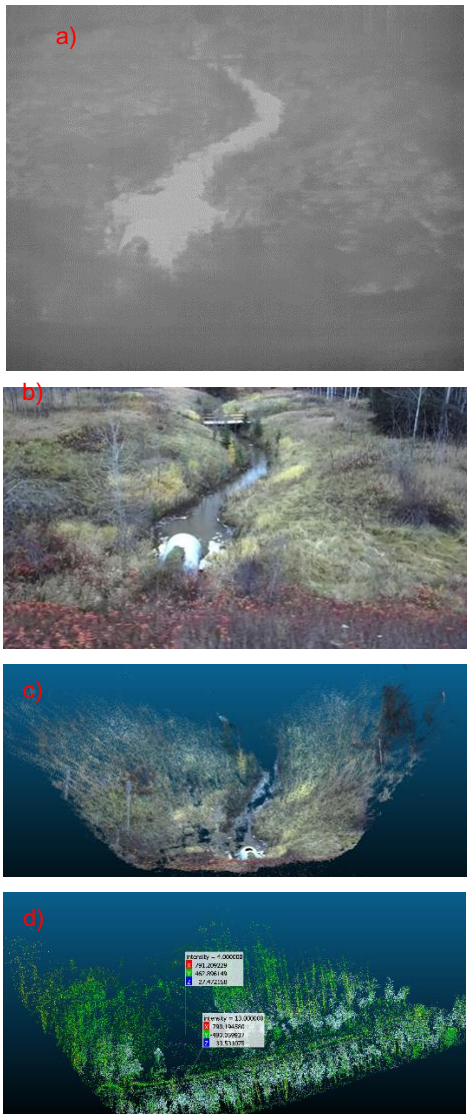

Figure 2. Water presence at the outlet of a culvert located under a rail track in an (a) infrared, (b) RGB images, and (c) 3D map generated by the SfM algorithm, (d) demonstrating calculation of water level from top of rail

3.2 Vegetation management at grade crossings

The safety of rail operations over grade crossings is a critical issue for Canada's railway industry. Accidents at grade crossing represents approximately one third of all fatalities and half of all serious injuries from railway accidents (Transport Canada, 2021b). Effective vegetation management near grade crossings is crucial for ensuring safe and secure train operations, as well as safeguarding the public and personnel. Inadequate vegetation control can lead to compromised sightlines at public crossings, increasing the risk of accidents.

Transport Canada sets the minimum requirement for the clear sightline area around each crossing. These sightlines must, at the minimum, provide crossing users with sufficient time to see and react to an oncoming train, from both the 'approach' and 'stop' positions. Sightlines clear area must be preserved by prohibiting the construction of buildings or structures, or the placement of objects that would obstruct the sightlines

The NRC's instrumented hi-rail truck offers a distinctive advantage with its capability to generate 3D maps of the track environment. These maps provide detailed insights into vegetation presence along the rail line, offering valuable information on sightline obstructions such as the height of potential hazard trees, and their proximity to the track. This automated approach, in comparison with the current visual inspections conducted by track inspectors, provides a more efficient means of quantifying the situation and allows for tracking changes over time.

Integration of measurements from scanning LiDARs and Inertial Measurement Unit (IMU) data is employed to create a 3D map of scanned locations through Simultaneous Localization and Mapping (SLAM) techniques. Utilizing two LiDARs positioned on the roof and back units enhances the precision of the 3D map, enabling its application in various railway inspection tasks.

Figure 3a shows a single LiDAR scan acquired within the track environment, and Figure 3b demonstrates a dense 3D point cloud representation of the track surroundings near a farm crossing. Following the acquisition of these maps, integration with Global Navigation Satellite System (GNSS) data collected by the hi-rail instrumentation facilitates the generation of a geo-referenced 3D map encompassing grades and farm crossings. Railway operators typically possess approximate GNSS coordinates for these crossings, allowing for automated identification within the generated 3D maps by referencing existing databases. Once the crossing locations are identified, the volume that is required to be free of obstructions can be determined in the 3D maps. Within these volumes, it is trivial to localize point cloud clusters above the track surface. Volumetric analysis of these clusters provides a mean to ascertain whether sightline obstructions are present. The geo-references videos from the cameras on the hi-rail truck can be replayed if further inspection

is desired. These problem areas can then be scheduled for remedial actions.

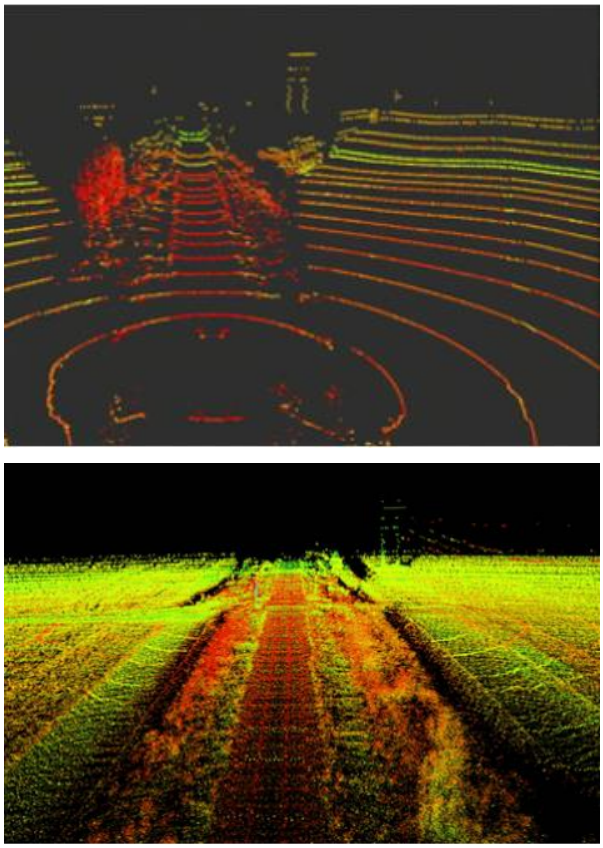

Figure 3. (a) A single LiDAR scan, (b) multiple LiDAR were registered together to create a 3D map of a farm-crossing.

4 CONCLUSIONS

This paper emphasized the crucial role of advanced technologies in enhancing the safety and efficiency of railway operations. The use of advanced sensors on mobile platforms has the potential to revolutionize track inspection processes, addressing challenges posed by climate impacts, increased rail traffic, and supply chain constraints. The preliminary results of hi-rail truck, equipped with sensors and advanced algorithms, suggested promising solution to address these challenges.

The practical applications of the hi-rail truck, demonstrated through successful mapping of surface water areas and vegetation along railway lines, showcase its potential in enhancing current track visual inspections. Going beyond traditional visual inspections, the truck offers an automated and detailed approach to identify issues within ROW. The discussions on water mapping and vegetation management not only showcase the truck's effectiveness but also its adaptability in enhancing safety protocols.

Looking forward, ongoing efforts to develop and optimize the hi-rail truck's hardware and software are underway. The integration of LiDAR, GNSS, and visual data streams provide a comprehensive approach to monitor and manage railway environments. As the industry continues to embrace emerging technologies, the instrumented hi-rail truck can find further applications, contributing to the ongoing evolution of railway track inspection practices.

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