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Thematic Excellence Program

Industry and Digitalisation

Application Domain Specific Highly Reliable IT Solutions

Error detection of railroad infrastructure in LiDAR point clouds

Máté Cserép[1], Adalbert Demján, Friderika Mayer, Balázs Tábori, Péter Hudoba[2]

ELTE Eötvös Loránd University, Faculty of Informatics

[1]mcserep@inf.elte.hu, [2]hudoba.peter@inf.elte.hu

Introduction

Monitoring the condition of railway infrastructure is essential for maintaining safety standards and preventing accidents. The regular inspections are still typically carried out in many countries with costly and time-consuming on-site human inspections. LiDAR point clouds collected by mobile laser scanning (MLS) already proved to be suitable for recognizing important railroad infrastructure elements, such as cables and the rail tracks. However, the computational requirement for processing these extremely large and dense point clouds is still a challenge nowadays, resulting in longer execution time than practically applicable.

In our research we have implemented and comparatively analyzed railroad fragmentation and object segmentation algorithms with the focus on robustness and high effectiveness: prioritizing automatization and prerequisite reduction (e.g. the spatial relationship between the railway track and the overhead contact line). These aspects also enables the easy parallelization for the processing of larger railroad segments.

Dataset

The sample LiDAR datasets were collected by the Hungarian State Railways (MÁV) with a *Riegl VMX-450* high density mobile mapping system (MMS) mounted on a railroad vehicle, as depicted in Fig. 1. The train was operating at 60 km/h, the sensor was capable of recording $1.1 * 10^6$ points / sec with a range precision of 3-7 mm and a positional accuracy of 3-5 cm.

Two datasets from different topographical regions of Hungary were selected:

1. *Szabadszállás - Kiskőrös* dataset, which covers an approximately 29 km long and 130 m wide rural railroad segment in Southern-Central Hungary and contains ca. $2.5 * 10^9$ points. This area is generally flat with minimal to no slopes on the rail tracks.
2. *Szentgotthárd neighborhood* dataset, which covers an approximately 5 km long and 90 m wide, partially rural and suburban railroad segment in Western-Hungary and contains ca. $0.8 * 10^9$ points. At foothills of the Alps, the topography is more varied and contains slopes.

Fig. 1. The *Riegl VMX-450* MMS sensor was mounted on a car, which was placed on a carriage.

Methodology

The proposed methodology shown in Fig. 2 contains of 3 major processing steps: *i*) *railroad fragmentation* receives a single large input point cloud and fragments it at the curves of the rail track. Hence the later processing steps, *ii*) *cable recognition* and *iii*) *rail recognition* will receive multiple smaller inputs, containing a mostly straight segment of the railroad. Cable and rail recognition can be evaluated independently and can be optimized to be executed parallelly. A possible follow-up, *iv*) processing step is the *error analysis* of the railroad infrastructure.

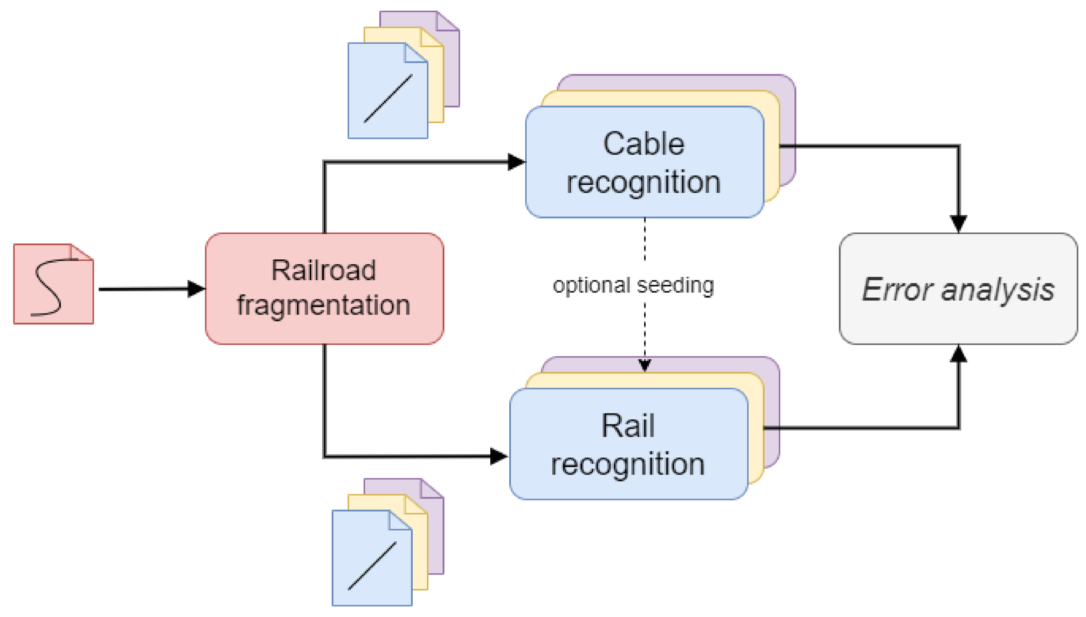

Fig. 2. Workflow diagram of the processing steps.

Railroad fragmentation

The curve of the rail track is detected using one the following methods: *i*) *Contour finding* with Suzuki's algorithm, preceded by an Otsu thresholding; *ii*) *Hough transformation* preceded by a Canny-edge detection; and *iii*) *Generalized Hough transformation* with its Ballard-defined version [4].

A curved rail track segment with the length of 600 and 1500 m were selected from both sample datasets to evaluate the railroad fragmentation. The longer segment from Szentgotthárd and its result are shown in Fig. 3. The execution time of each method can be found in Table 1.

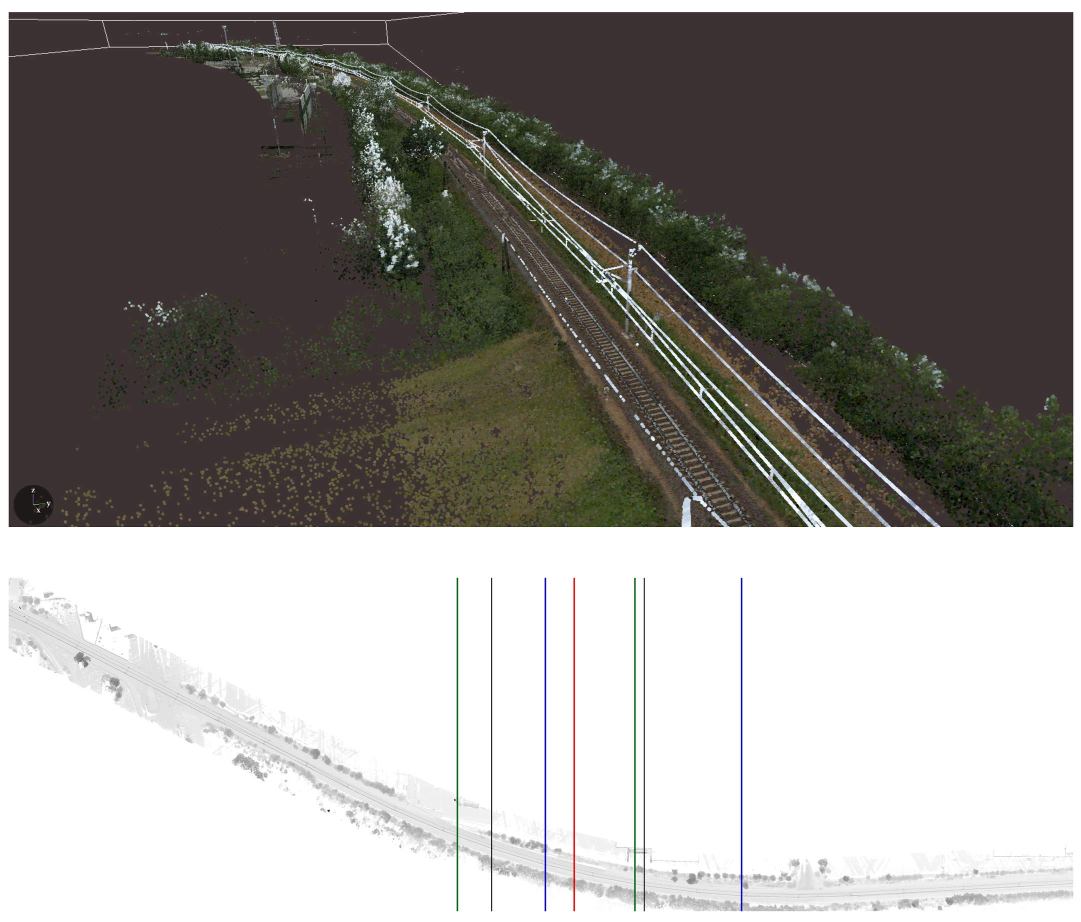

Fig. 3. Curve detection result for contour finding, Hough trans., Generalized Hough trans. and manual measurement (maximum allowed curve was 10°).

Algorithm	Szabadszállás	Szentgotthárd
Contour finding	2 m 52 s	9 m 10 s
Hough trans.	2 m 36 s	8 m 59 s
Gen. Hough trans.	3 m 11 s	13 m 7 s

Table 1. Runtime results of the rail fragmentation.

Object recognition

Three algorithms were implemented and compared for cable segmentation: *i*) a 2D Hough transform in a digital elevation model (DEM) constructed from the point cloud along the Z axis with the maximal Z coordinate in each grid cell is used as its value [1]; *ii*) a 3D Hough transform for line detection; and *iii*) a region growing approach [2]. The rail recognition was specified as an adapted and optimized version of Arastounia's proposed algorithm [5]. The original method assumed that the trackbed is mainly flat, with very little variance, which we found not to be the case in our datasets. The developed algorithm was enhanced with proper slope detection and handling [3].

To evaluate and verify the accuracy of the object recognition algorithms, both the cables and the rails for a 100 m long segment consisting of 7,316,298 points were annotated from the first dataset. This railroad segment and the visual output is displayed in Fig. 4, while the numerical evaluation results are in Table 2.

Algorithm	Runtime	Remaining points	False negative	False positive
Hough 2D	3.11 s	23,397	7.77 %	2.24%
Hough 3D	2.38 s	38,291	0%	35.23 %
RG	0.16 s	24,121	3.06 %	0.33 %
Rail track	67.18 s	67,368	3.16 %	1.52 %

Table 2. Accuracy of object recognition algorithms.

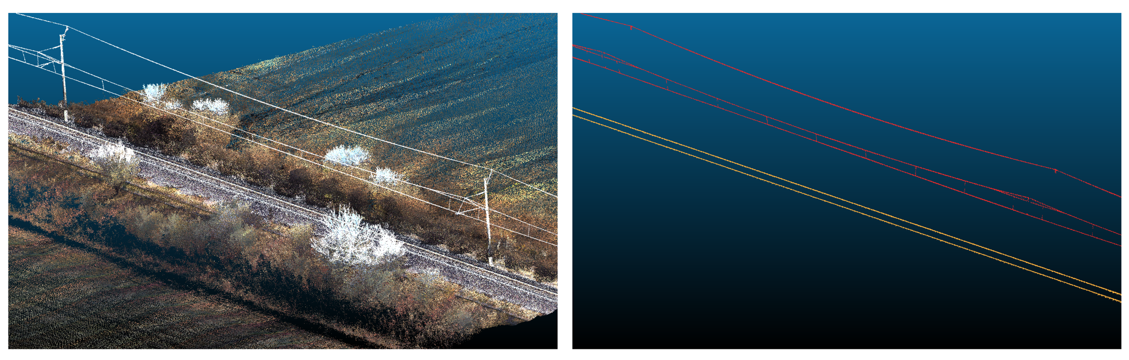

Fig. 4. Selected verification area and the combined visual result of the cable and rail track detection.

Error detection

Following the successful recognition of the cables and rails, the automated detection of possible errors and anomalies in the railroad infrastructure and its surrounding can be evaluated. Typical issues could be:

- improper height of overhead contact cable
- horizontal deviation of the cables
- possible collision in the clearance gauge (e.g close vegetation)
- deformation of the railway bedding
- sinking of the railway sleepers

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Source code availability: `https://github.com/mcserep/railroad`

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