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Automatic Shunting Operations (ASO) – Aspects for the Technical Solution

Burkhard Stadlmann[1], Thomas Penkner[1], Georg Schneider[1], Karl Zöchmeister[2], Adrian Wagner[3], Jürgen Zajicek[4]

[1]University of Applied Sciences Upper Austria – burkhard.stadlmann@fh-wels.at

[2]ÖBB Infrastruktur AG

[3]St. Pölten University of Applied Sciences - Carl Ritter von Ghega Institut for Integrated Mobility Research

[4]AIT Austrian Institute of Technology GmbH

Abstract

Shunting operations are of high importance for rail freight traffic. Progressive automation of individual shunting processes is therefore a natural consequence. This paper will present the overall technical solution for automatic shunting on tracks with open access. In addition to Automatic Train Operation (ATO) this will be called Automatic Shunting Operation (ASO). Two main use cases will be covered: (1) The fully automated and unmanned operation of the shunting loco serving the gravity hump within the marshalling yard; (2) Shunting operations including last mile operations with a single person on board for supervision. In order for the system to automatically detect obstacles within the clearance and signals along the track, a sensor solution for the locomotive will be presented. Finally, our approach for the automated coupling process will be explained.

Keywords: Automatic shunting operation, obstacle detection, track detection, automatic yard operation, ATO.

1 Introduction

Shunting operations are of high importance for rail freight traffic. The goal of the ongoing Austrian project autoSHUNTING is the automatic shunting within the marshalling yard and during last mile delivery.
This paper will consider two different shunting scenarios (1) shunting within a marshalling yard and (2) shunting during last mile delivery. Both shunting modes are especially relevant for single load freight traffic.

There are other R&D-projects ongoing with a similar goal [1] [2] [3] but autoSHUNTING aims to cover all relevant aspects for the below mentioned use cases.

This paper will present the overall technical solution for achieving this goal. As shunting operations take place on tracks with open access several challenging requirements must be fulfilled:

- The leading unit requires sensors for obstacle detection with high reliability and safety.
- The availability of sufficient information for automatic train operation (ATO) will not be equal to ATO over ETCS (see e.g. [4]). Additional specifications for automatic shunting operations (ASO) will be required.
- The leading unit must be capable of automatic detection and interpretation of several static and dynamic signals.
- The braking behaviour of shunting units may be unclear or even unknown.
- Automatic coupling shall be performed reliably. Locomotives are currently equipped with an automatic shunting coupler. After the introduction of the European Digital Automatic Coupler (DAC) this coupling device will make shunting easier.
- If the shunting unit is arranged with the locomotive at the end and the wagons are pushed, the leading wagon of the shunting unit is not equipped with sensors for obstacle detection. In this case it will be assumed that the single person doing the shunting operation will be positioned at the head of the shunting unit using a remote-control device for the engine.

Thus, autoSHUNTING will cover two main use cases which have been specified with the Austrian Federal Railways (ÖBB).

(1) The automated operation of the shunting loco serving the gravity hump within the marshalling yard. The operation shall be Grade of Automation 4 (GoA 4) without any staff on board. The engine will push the train to the hump and afterwards returns back to get to the next train. (UC1)
(2) Other shunting operations covering additional operations in the marshalling yard as well as last mile operations. There will be one person on board of the shunting unit for supervision and as a human sensor when pushing the shunting unit. (UC2)

2 Methods

The project autoSHUNTING has developed a system of demonstrated solutions for Automatic Shunting Operations (ASO).

Sensor system

A sensor frame has been developed which might be mounted on a standard shunting loco class 2070 of ÖBB. Figure 1 depicts this frame with the mounted sensors: (1) cameras for obstacle detection, track detection, and signal detection; (2) Radar and LIDAR sensors for obstacle detection; (3) Ultrasonic sensors to reliably cover nearfield blind spots in obstacle detection; (4) GPS antenna to be fused with inertial and odometer measurements for localisation.

Figure 1: Sensor frame

Localisation and Obstacle Detection:

The six axes localisation is implemented as a multi-dimensional Kalman filter with appropriate filtering of the input data.

The obstacle detection merges the input of the above mentioned different sensors to achieve a robust detection of any objects within the clearance. Figure 2 shows its basic architecture.

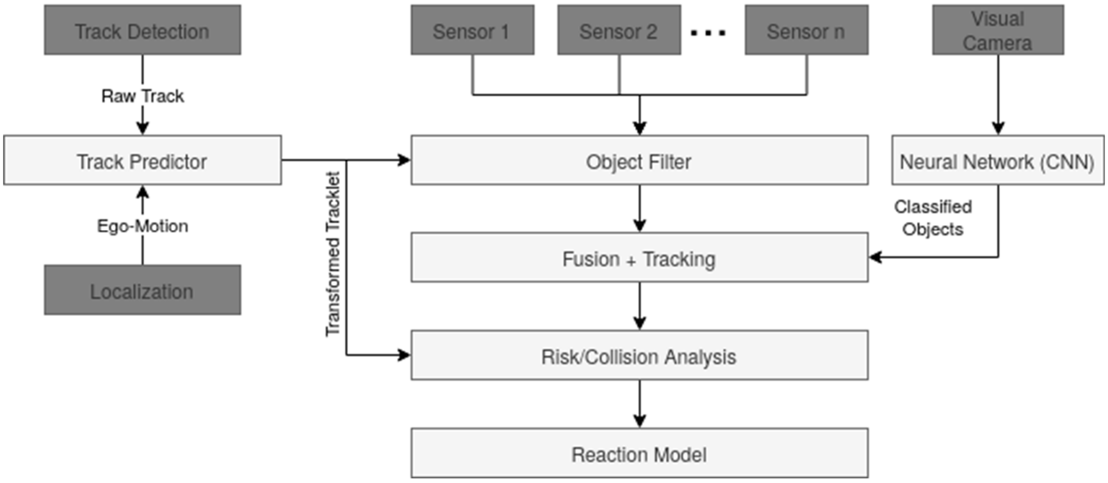

Figure 2: General Software Architecture of the obstacle detection

Obstacle detection for automated train operation has been covered by multiple publications. While camera based solutions mainly handle known object types (e.g. [5]), active sensors such as LIDAR or Radar cover any object that sufficiently reflects the emitted sensor signal (e.g. [6][7]).

Track Detection:
The track detection is implemented in two ways:
(1) ÖBB is working on a corresponding project that will allow the on-board unit to read the digital twin data of the infrastructure. This includes the detailed route data of the interlocking in selected stations. A special interface has been implemented for receiving such data.
(2) As a stand-alone solution the route will be estimated using a camera-based algorithm, which combines elements of Artificial Intelligence and classical image processing. The algorithm works well but the detection of the state of the points is limited to a comparable small distance depending on the light situation. As long as the state of the point in front of the engine is not known, all possible routes are considered for the movement and the obstacle detection.

Signal Detection:
Signal detection was achieved by implementing state-of-the-art machine learning algorithms appropriate for object detection in images. The training database consists of a large amount of photos of relevant shunting signals, including light signals as well as static signal posts. In this field of research many other proposals are published (like [8] [9] [10]). However, the presented solutions of autoSHUNTING consider the shunting environment especially.

In addition, the afore mentioned on-board system of the ÖBB will be able to deliver real-time information about the state of the light signals.

3 Results

The results for the technical solution of ASO are.

System architecture
Figure 3 depicts the system architecture of the on-board-system and the interface to the interlocking. The on-board system covers all elements required for the automatic movements of the engine.
The interface to the interlocking depends on the kind of interlocking available at the site.

- If there is an electronic interlocking available, the afore mentioned ÖBB project will deliver relevant data for the track detection and the state of the signals.
- If there is an electromechanical or mechanical interlocking, the engine shall be able to interpret the shunting signals in addition to the one person staff on board.

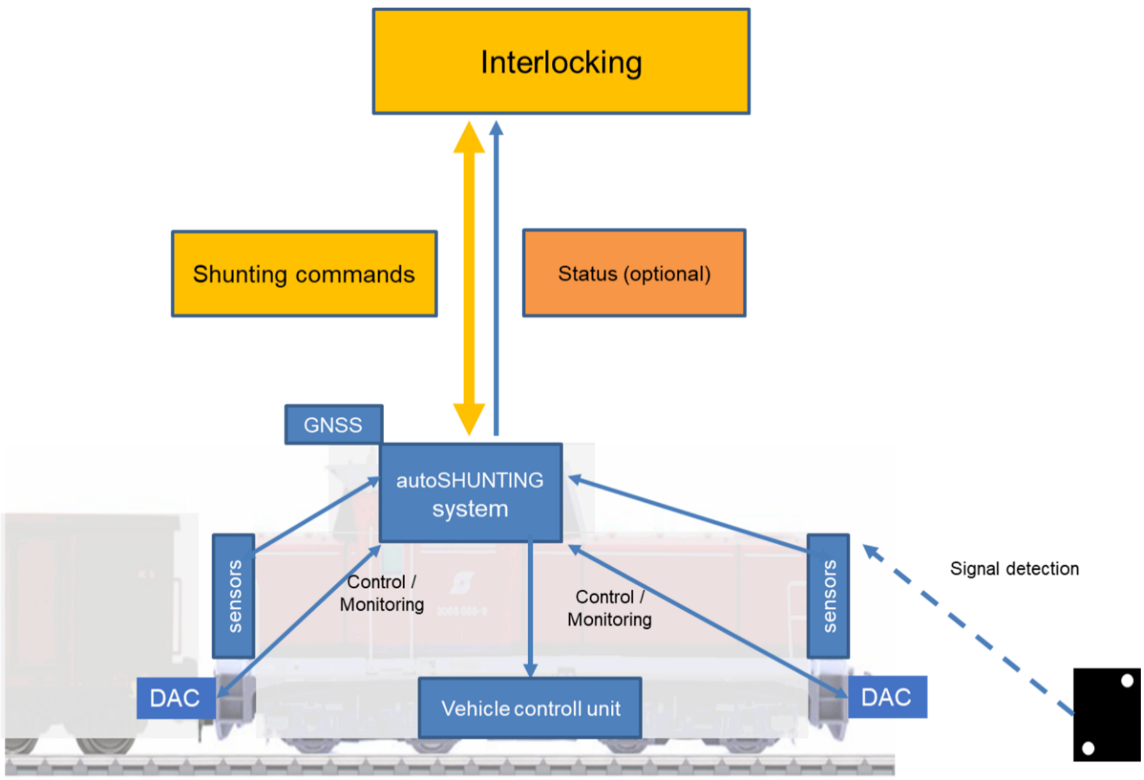

Figure 3: System Architecture for ASO

Obstacle detection and localisation

Figure 4 shows a cardboard box placed within the clearance detected by the LIDAR sensors. Combining the localisation solution and the current route, the system estimates an imminent collision and stops within a safe distance.

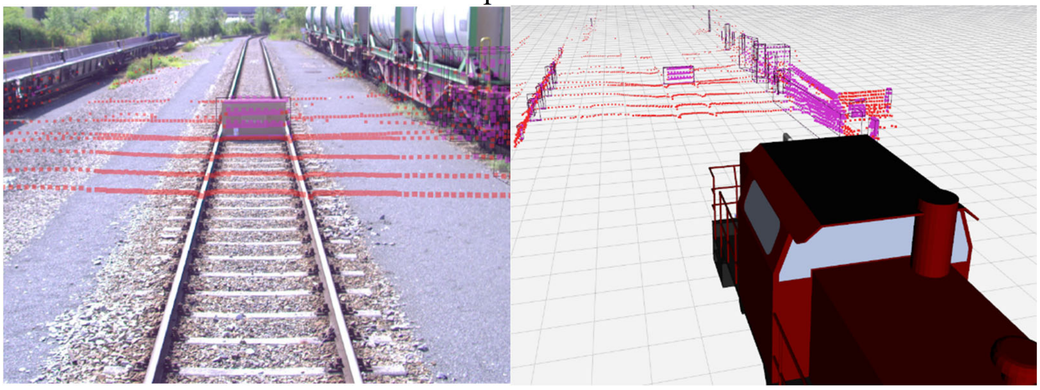

Figure 4: Example for obstacle detection

Track detection

Figure 5 depicts the sequential results of the above-mentioned stand-alone solution for the track detection: (top-left) raw image; (top-right) semantic segmentation solution; (bottom-left) extracted track points; (bottom-right) generated track paths.

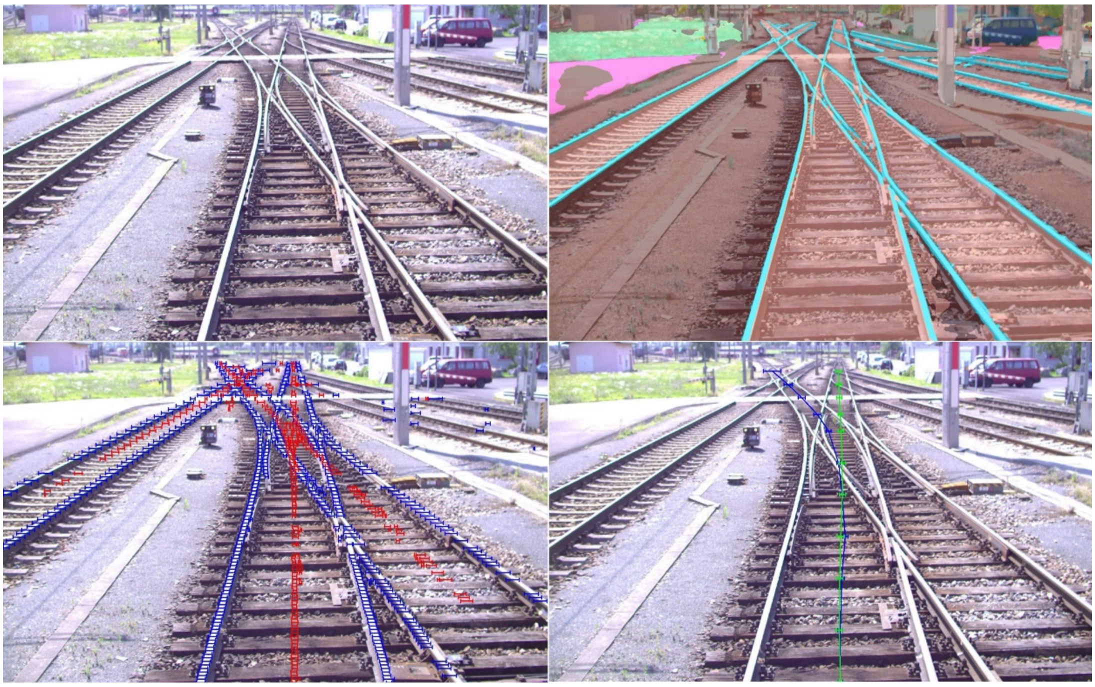

Figure 5: Example for track detection

Signal detection

Figures 6 and 7 depict examples of the implemented signal detection. Based on pictures from an Austrian marshalling yard the algorithm has interpreted the scene. The stated figures give the probability of the detection of the appropriate signals.

Figure 6: Example 1 for signal detection

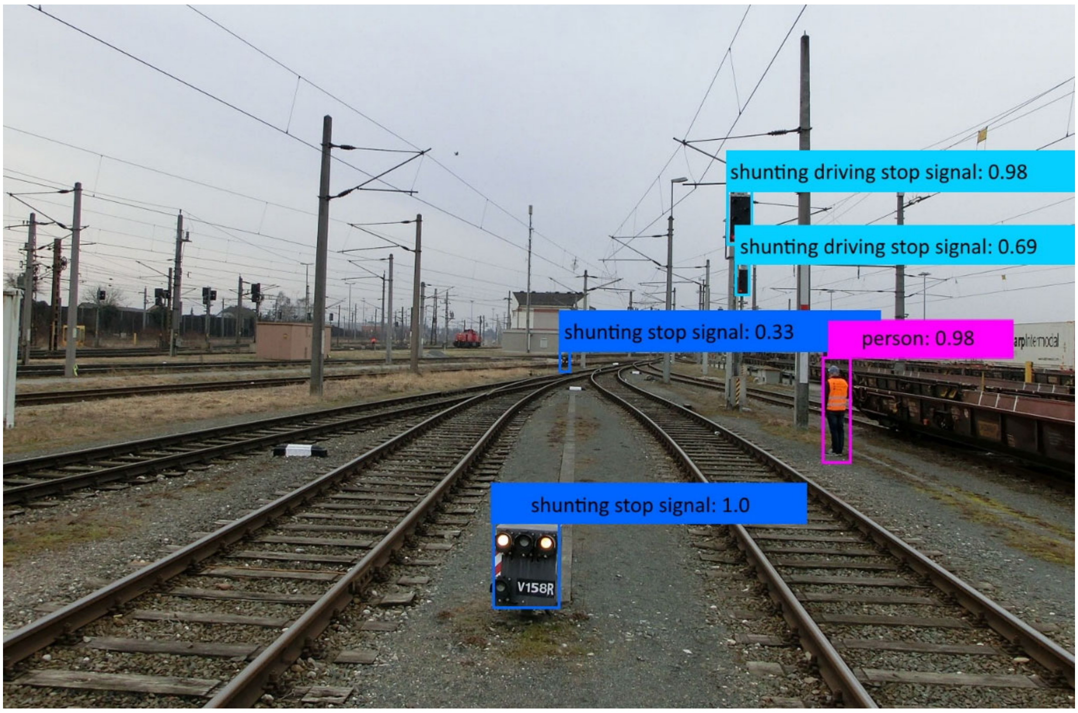

Figure 7: Example 2 for signal detection

Automatic Coupling
Figure 8 depicts the principal sensor equipment for the detection of the coupling. After the introduction of the DAC the sensor will be adapted accordingly due to the absence of the bumpers.

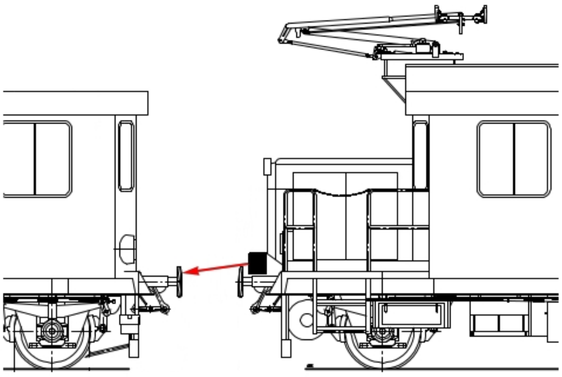

Figure 8: Sensor for coupling detection

Figure 9 depicts the signal of the acceleration sensor during a coupling operation. It is clearly visible that the physical contact between locomotive and wagon results in distinct sensor readings.

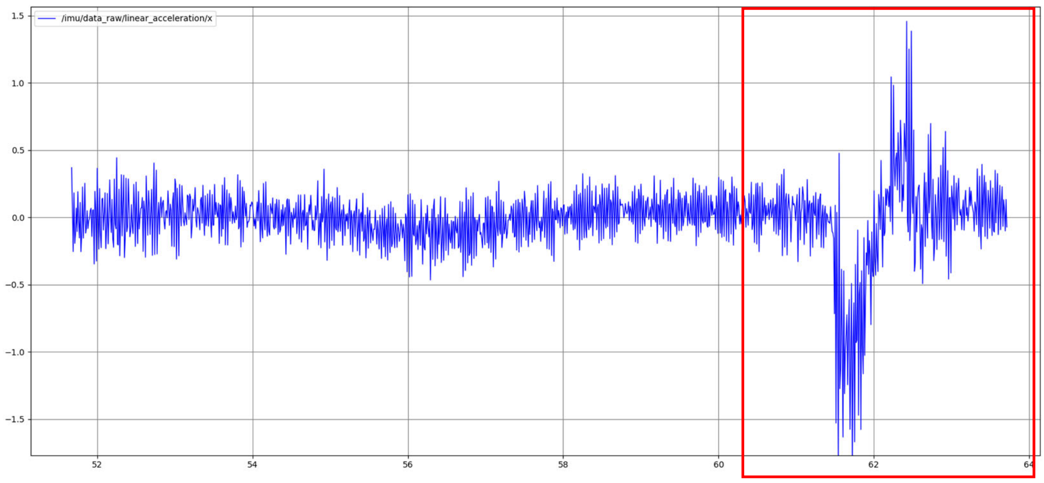

Figure 9: Recorded acceleration during coupling process

Commands for the Drive Control Unit
Appropriate commands for the drive control unit of the engine (speed, acceleration, signal horn, etc.) are based on the results of the obstacle detection and its collision risk analysis, the length of the detected route, and the results of the braking tests when changing the configuration of the shunting unit. This will allow GoA 4 operation.

4 Conclusions and Contributions

The presented results lead to the following conclusions:

Within the project autoSHUNTING selected shunting operations have been tested in the marshalling yard of Wels in Austria. Further testing will take place nearby Vienna in spring 2022. The developed sensor solution is capable of controlling the engine in a marshalling yard with its complex track topology.

The localisation is sufficiently accurate in all six axes and does not need a route map. The track detection is based on two different possible solutions using either data from the interlocking if available or detecting the track using the on-board camera. The combination of the results of autoSHUNTING with the parallel ÖBB project lead to a sound basis for real GoA 4 operation of shunting units in the marshalling yard and during last mile operation.

The obstacle detection will find relevant obstacles like persons or objects on the track as well as other wagons when executing a coupling process using an automatic coupler. The obstacle detection has been tested with different light situations including night operation.

This paper presents all basic aspects of the technical solution for automated shunting operations (ASO).

Future work will be required for the demonstration of long-term reliability with a designated shunting engine.

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