Horizon 2020
European Union Funding
for Research & Innovation

Deliverable D 4.3

Guideline document on object detection

Project acronym:	GoSAFE RAIL
Starting date:	01/10/2016
Duration (in months):	36
Call (part) identifier:	H2020-S2R-OC-CCA-04-2015
Grant agreement no:	730817
Due date of deliverable:	Month 24
Actual submission date:	05-10-2018
Responsible/Author:	Meho Sasa Kovacevic, University of Zagreb
Dissemination level:	PU
Status:	Final

Reviewed: yes

This project has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 730817.

Document history		
Revision	*Date*	*Description*
1	30/09/2018	First issue
2	05/10/2018	2nd issue
3	31/10/2018	Final

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Table of Contents

1. Executive Summary

This report presents an overview of different monitoring systems for object detection on railway networks. An overview of state-of-the-art detection technologies and their features is given, highlighting the detection range and angle, advantages and disadvantages, as well the area of application for each technology. A demonstration project performed during the GoSAFE RAIL project by the University of Zagreb in collaboration with HZ Infrastructure on the use of image detection on safety-critical sectors of infrastructure of the Croatian Rail network is summarised. An advanced image processing technique for obstacle detection was applied and this deliverable discusses common problems that arose during obstacle detection process and proposes possible solutions to overcome these problems.

2. Abbreviations and acronyms

Abbreviation / Acronyms	Description
ATO	Automatic Train Operation
CCA	Cross cutting area
GIS	Geographic Information System
I2M	Integrated Mobility Management
LiDAR	Light Detection and Ranging
TD	Technical Demonstrator

3. Background

The present document Deliverable D4.3 “Guideline document on object detection” contributes to the TD 5.6 of IP5, Autonomous train operation and CCA Work Area 4 Smart Mobility, Sub-work area 4.2 Integrated Mobility Management (I2M) (Shift2Rail Joint Undertaking, Multi-Annual Action Plan, Brussels, November 2015), by proposing a new object detection system in order to improve vehicle, human and big animal detection on tracks, and specifically on safety-critical sectors of infrastructure, such as level crossings, bridges and tunnels. This deliverable, as a result of efforts done through the GoSAFE RAIL Work Package on ‘Demonstration and implementation’, provides demonstration of the project outputs on live railways. Therefore, demo project ensures that the outputs from the project will be implemented in the practice of infrastructure management within and beyond the life of the project.

4. Objective/Aim

Current sensor technologies adopted in the in-land transport applications are capable of sight distances of around 200m. Because of the long stopping distances of trains, systems used in this domain need to look ahead up to 1,000m detecting objects on and near track which may potentially interfere with the clearance and ground profile. In addition, the system should safely identify patterns and be capable of differentiating static and dynamic objects e.g. the position of trackside poles from a human. (*Shift2Rail Joint Undertaking, Multi-Annual Action Plan, Brussels, November 2015*)

This document has been prepared to provide a shot description of the implementation of different monitoring system, based on the work conducted in the Task 1.3 and Task 1.4 of the GoSAFE RAIL project.

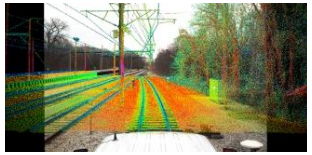
5. Overview of methods for obstruction detection on tracks

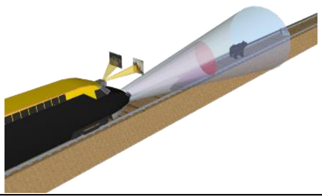
A train often travels at a speed where the stopping distance is about one kilometre. Because of obstacles (anomalies) in the terrain and challenging weather conditions it can be difficult for the train driver to see anomalies on the railway far away, especially in the dark. Thus, it is often hard to stop in time to avoid a collision. Because of the large stopping distances, the presence of large radii vertical and horizontal curves and linear nature of rail lines, detecting track obstructions including vehicles, humans and animals is a continuing challenge. This report first gives an overview of a range of solutions designed to identify particular hazards, before reporting a demonstrator project applied on a section of the rail network in Croatia, in collaboration with HŽ Infrastructure. The systems considered included; a Radar System, a multi-sensor train mounted system utilising high resolution cameras and image processing techniques will be deployed to identify hazards such as animals, humans or other objects that block the track, Fixed camera systems used at critical points such as level crossings and tunnel entrances, LIDAR scanners complemented with radar systems operating at a range of frequencies to detect obstructions tested on the Croatian Rail network and Drones in combination with train mounted high resolution cameras.

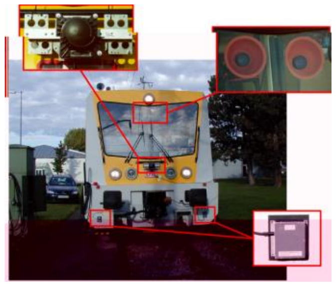
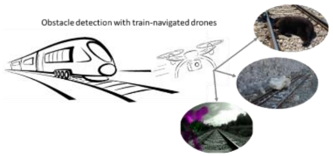
An overview of existing technologies is given in Table 1, with their main technical limitations.

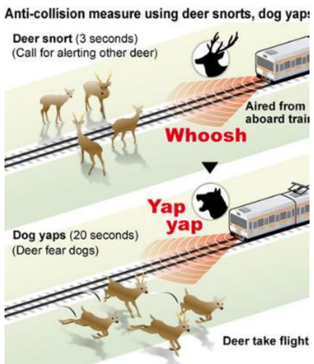
Table 1 Overview of detection technologies and their features

Type of detection technology/sensor	Detection range	Detection angle	Advantages	Disadvantages	Application
Automatic Radar system  (www.prweb.com/releases/ 2009/08/prweb2707134.htm)	> 60m	<10 deg	• Stable detection regardless of rainy, snowy or foggy weather and night time lighting, • The ability to perform detection over an entire area with significant detection distances, • Capability for direct speed measurement with high target movement prediction performance • Good performance in bad weather conditions (rainy, snowy or foggy conditions) e.g. 3 millimetre wavelength enables the radar signal penetrate into a long narrow smoky tunnel	• low transversal resolution which causes remarkably rough estimation of the obstacle's position	• Level crossings (short range high resolution radar) / detects objects that enter the area before or while the gates are closing and provides a warning to approaching trains via the existing signalling system • Tunnels (Narrowband millimetre wave radar)

Type of detection technology/sensor	Detection range	Detection angle	Advantages	Disadvantages	Application
Lidar (3-D laser scanning) 	> 80m	Horizontal angle of view 60 deg Vertical angle of view 30 deg	• Measurement gives a 3D point cloud with 3D coordinates of all points, which allows detection of small obstacles. • Machine learning trainings, with the amount of trainings the system becomes "smarter" • Detection time 0.5 s or less	• the obstacles of unknown classes cannot be detected. • relatively expensive • mathematically very demanding and time consuming.	• Level crossings / recognizes 3-D objects in the area of level crossing
Train mounted thermal camera  (Berg et al., 2015)			Pilot project with the train driving at about 200 km/h on a railway which slightly bends to the right.	Minimum temperature difference of $\Delta T \geq 5^{\circ}$ is needed.	

Type of detection technology/sensor	Detection range	Detection angle	Advantages	Disadvantages	Application
Fixed high resolution cameras  	> 100m	<10deg >30deg	Applies image processing technique. Image and/or pattern recognition, ability to identify objects, places, people, writing and actions in images. Computers can use machine vision technologies in combination with a camera and artificial intelligence software to achieve image recognition.	• Particular susceptibility to ambient light in backlit scenes, rainy/foggy weather, etc. • Low accuracy in terms of distance to target objects	• Level crossings • Critical areas of open track
Multi-sensor train mounted system (e.g. tele camera, a far distance radar, a survey camera and a near distance radar network) 	Large distances	/	Combining a radar sensor offering long-distance detection performance and an optical image sensor for short distance works in a complementary way. This enables covering short and large distances in all angles. Image processing techniques are deployed.	Expensive	Open track

Type of detection technology/sensor	Detection range	Detection angle	Advantages	Disadvantages	Application
Multiple frequency radar system  (Kruse et al. 2003)	Large distances	/	This technique employs a machine learning approach, to allow can detection of pre-trained obstacle classes, such as humans, animals, cars, train, rock falls etc.	Unknown obstacles cannot be detected	Open track
Drones equipped with high resolution cameras flying in front of the train  	Large distances		Application of photogrammetry which provides number of outputs (map, drawing, measurement, 3D model of some real-world object or scene) Images can be used for many purposes (inspection, monitoring)	Limitations of the drone battery Navigation. Not applicable in the populated areas.	Open track

Type of detection technology/sensor	Detection range	Detection angle	Advantages	Disadvantages	Application
Noise systems (the blaring of the animal sounds from aboard the running train)  (http://www.asahi.com/ajw/articles/AJ201801170001.html)	/	/	3-second-long recording of a deer's snort and 20 seconds of a yapping dog were aired from aboard a running train car between evening and late at night, the time of the day when deer typically make frequent appearances. Cheap	Not applicable in the populated areas.	Open track. Tunnels

6. Demonstration case study for obstacle detection

A demonstration project of a vehicle mounted object detection system was performed on a section of the Croatian railway network between Zagreb and Rijeka. Having scanned the section of the track an advanced image processing technique for obstacle detection was applied. Common problems that arise in this process are analysed and possible solutions are proposed. Image comparison proved to be the most useful technique considered for obstacle detection using a simple subtraction method between images taken in a different moment in time. The fact that only one mathematical operation of image subtraction is needed in processing this technique makes this method simple and easy to apply.

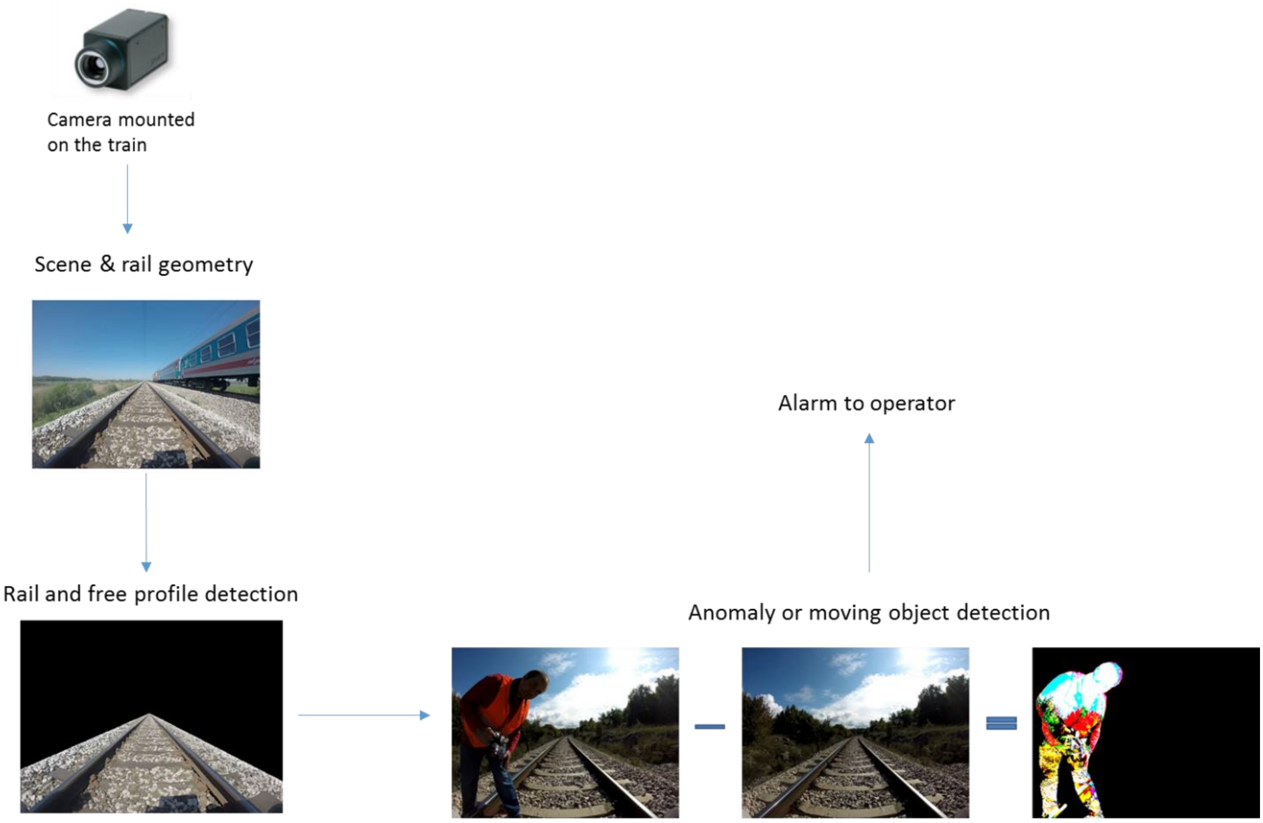


Figure 1. Process of using cameras for object detection on the track

The technique involves the use of video recordings to extract images from different time intervals and analyse them to detect obstacles. Since the pictures/images can be transformed into matrices, simple subtraction of one picture from another can be performed (the process is shown in Figure 1), leading to only one matrix at the end with only one mathematical operation.

If the pictures are the same the outcome will be matrix with all zeros meaning a black picture. The technique works fastest if applied on black and white pictures. A problem can arise if an object is too small and cannot be detected on a simplified black and white image. A detailed description of the technique is given in Deliverable 1.3 - Report on monitoring system for obstruction detection from the GoSAFE RAIL project.

This is a method that can be used with both fixed and in-vehicle camera systems with certain differences in the methodology. The method is based on detecting obstacles by **subtracting present and past in-vehicle camera images**. There can be various obstacles obstructing traffic so detecting can be a challenging task. The area is developing rapidly and there are several techniques to detect forward obstacles available but still most of them detect only specific obstacles. They use various sensors such as millimetre-wave radar, stereo or monocular camera or infra-red camera, each having their own restrictions.

7. Conclusion

This document outlines the state of the art technologies for obstacle detection and research efforts for innovative solutions applied at the case study in Croatia. This report contributes to the TD 5.6 which aims at a state-of-the-art development in multiple dimensions relevant to rail freight.

The main focus for obstacle detection applications was on level crossings, where the majority of accidents occur, in order to prevent a train colliding with an object such as a vehicle stuck on the crossing. Increasing safety consciousness, however, has prompted railway companies to install more advanced systems than those that have been used conventionally. Nevertheless, the number of incidents on open track sections is increasing, as well as the developments for autonomous train implementations. The need for a multiple-sensor approach developed from the fact that every single-sensor system has certain disadvantages which limits its capability. This is of importance since high demands are made on the measurement range, precision and response time.

The sensor technologies in current land transport research are able to look some 200m ahead. The required rail obstacle detection interfacing with train control will be able to look ahead up to 1,000m detecting objects on and near track which may potentially interfere with the clearance and ground profile. It will safely identify patterns knowing to differentiate the trackside infrastructure from objects that should not be on the track.

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