SMART: a novel on-board integrated multi-sensor long-range obstacle detection system for railways

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SMART project ID card

Shift2Rail  H2020 Collaborative RIA Project
SMART-Smart Automation of Rail Transport

- Total budget: 999.598 €
- Consortium: 5 participants from 3 European countries
- Project start: 1st October 2016; Duration: 36 months
  ➢ Kick-off meeting at RAILCON’16
SMART project objectives

To increase the effectiveness and capacity of rail freight through the contribution to automation of railway cargo haul at European railways by developing of:

- a prototype of an autonomous obstacle detection (OD) system, and
- a real-time marshalling yard management system
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SMART partners in Obstacle Detection (OD) work stream

University of Niš

Universität Bremen

IFS

RWTH Aachen University

HARDER
digital
SOVA

SmarT

Shift2Rail

European Union Funding for Research & Innovation
SMART obstacle detection (OD) system

- According to the Shift2Rail Multi-Annual Action Plan-MAAP, Shift2Rail (2015), one key challenge, which has so far hindered automation of rail freight systems, is the lack of a safe and reliable on-board obstacle detection system within existing infrastructure.

- SMART will contribute to tackling this challenge by the development, implementation and evaluation of a prototype integrated on-board multi-sensor system for reliable detection of potential obstacles on rail tracks.
SMART obstacle detection system

- State-of-the-art obstacle-detection on rail tracks ahead of a train
  - relatively short range obstacle detection, up to 100 m
  - mostly used for day vision

- **SMART** will be a novel fully integrated multi-sensor on-board system for mid (up to 200 m) and long range (up to 1000 m) obstacle detection, which can operate in day and night conditions as well as in poor visibility conditions
Concept of the SMART multi-sensor obstacle detection system

➢ Sensor Fusion:
  ✓ two pairs of stereo cameras C1-C3; C1-C2
  ✓ Thermal vision
  ✓ Night vision
  ✓ Laser scanner
Integrated multi-sensory OD system

- Sensors housing which will enable mounting of the OD system on different test vehicles

Initial version of the CAD model of the sensor housing of the integrated ODS demonstrator

Frontal profile of a SMART test vehicle, Serbia Kargo ŽS series 444, with possible locations of the ODS demonstrator (grey rectangulars)
Integrated multi-sensory OD system

- Final design of sensors housing which will enable mounting of the OD system on different test vehicles

![Diagram of sensors]

- Thermal camera
- 3D laser scanner
- Night vision camera
- Stereo cameras C1 and C3
- Stereo cameras C1 and C2
Integrated multi-sensory OD system

- Final design of sensors housing which will enable mounting of the OD system on different test vehicles
Integrated multi-sensory OD system

- Final design of sensors housing which will enable mounting of the OD system on different test vehicles

![Image of multi-sensory OD system with labeling]
Integrated multi-sensory OD system

- Field tests performed on Serbian railway test-site, 27th-28th March 2018:
Integrated multi-sensory OD system

- Field tests performed on Serbian railway test-site, 27\textsuperscript{th}-28\textsuperscript{th} March 2018:
Integrated multi-sensory OD system

- RGB camera
- Stereo camera
- Thermal camera
- LiDAR
- Night vision camera

Actual Scene
3D point cloud
3D point cloud
Integrated multi-sensory OD system

Thermal camera

LiDAR

Stereo camera

Night vision camera
Integrated multi-sensory OD system

RGB camera

Actual Scene

Stereo camera

3D point cloud

Thermal camera

LiDAR

3D point cloud

Night vision camera

Shift2Rail

Horizon 2020 European Union Funding for Research & Innovation
Integrated multi-sensory OD system

- RGB camera
- Actual scene
- Stereo camera
- 3D point cloud
- Thermal camera
- LiDAR
- 3D point cloud
- Night vision camera
SMART OD software

- A novel machine learning-based method for long-range obstacle detection and distance estimation from a single monocular camera

**DisNet**: learning the change in object appearance in an image (in terms of size) due to the change of the object distance with respect to the camera viewing the object
**SMART OD software**

- **DisNet Structure** - ANN with 3 hidden layers with 100 hidden neurons per layer.

- **Supervised learning** for the training of DisNet:
  - training set of 2000 features;
  - ground truth - LiDAR distance measurement
SMART OD software

**Dataset** - manually extracted bounding boxes of different objects from the RGB images labelled with real distance measured using LiDAR.

**Features** –

\[ \mathbf{v} = \begin{bmatrix} 1/B_h & 1/B_w & 1/B_d & C_h & C_w & C_b \end{bmatrix} \]

- \( B_h \) = (height of the object bounding box in pixels/image height in pixels)
- \( B_w \) = (width of the object bounding box in pixels/image width in pixels)
- \( B_d \) = (diagonal of the object bounding box in pixels/image diagonal in pixels)
- \( C_h, C_w, C_b \) are the values of average height, width and breadth of an object of the particular class.
## Evaluation results - static field tests

<table>
<thead>
<tr>
<th>Ground Truth</th>
<th>RGB Camera</th>
<th>Thermal Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person 1</td>
<td>54.26 m</td>
<td>48.36 m</td>
</tr>
<tr>
<td>Person 2</td>
<td>132.26 m</td>
<td>161.02 m</td>
</tr>
<tr>
<td>Person 3</td>
<td>167.59 m</td>
<td>157.02 m</td>
</tr>
<tr>
<td>Person 4</td>
<td>338.51 m</td>
<td>not-visible</td>
</tr>
<tr>
<td>Person 5</td>
<td>not-visible</td>
<td>469.94</td>
</tr>
</tbody>
</table>
Evaluation results-dynamic field tests-OD scenarios

- SERBIA CARGO Locomotive 444-018
- No wagons; Total mass 80 t; Total length 15 m
Evaluation results-dynamic field tests-OD

Real-time obstacle detection with RGB cameras

Distance to person: 121.74 m

Distance to person: 114.16 m

Distance to person: 86.37 m
Evaluation results - dynamic field tests

- SERBIA CARGO Locomotive 444-018
- 21 wagons
- Total mass 1194 t; Total length 458 m

- Part of Corridor X to Thessaloniki
- Length 120km
- Max speed 80 km/h
Evaluation results-dynamic field tests-Real world scenario

Real-time obstacle detection with the thermal camera

Real-time obstacle detection with RGB cameras
Evaluation results - dynamic field tests - Real world scenario
Evaluation results-dynamic field tests-Real world scenario

DETECTED CRITICAL SITUATION!
Evaluation results-dynamic field tests-Real world scenario

DETECTED CRITICAL SITUATION!
Evaluation results-dynamic field tests-Real world scenario
DETECTED CRITICAL SITUATION!
Special thanks to:
- Serbian Railways Infrastructure
- Serbia Cargo
for support in realization of the SMART OD field tests.
Thank you for your attention!

www. smartrail-automation-project.net
Concept of the SMART multi-sensor obstacle detection system