SMART
SMart Automation of Rail Transport

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Overview

- H2020 Shift2Rail project SMART-SMarto
  Automation of Rail Transport
- Autonomous obstacle detection
- Real-time marshalling yard management system
SMART project ID card

Shift2Rail  H2020 Collaborative R&D Project
SMART-Smart Automation of Rail Transport

- Total budget: 999,598 €
- Project start: 1st October 2016; Duration: 36 months
- Consortium: 5 participants from 3 European countries
- Collaboration: ARCC
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 system, and
- a real-time marshalling yard management system
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:

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- a real-time marshalling yard management system
SMART obstacle detection 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
Concept of the SMART multi-sensor obstacle detection system
Evaluation of the SMART obstacle detection system

- Several evaluation scenarios
  - Testing track of the Department for Rail Vehicles and Transport Systems (IFS) of RWTH Aachen
  - Serbian railways network using the vehicle, the electric locomotive ŽS series 444, owned by “Serbia Cargo” (http://srbcargo.rs)
Evaluation of the SMART obstacle detection system—Preliminary results

- Testing track of the Department for Rail Vehicles and Transport Systems (IFS) of RWTH Aachen – August 2017

IFS Research Vehicle (former CargoMover AGV)

Sensors mounted on the front rail of the IFS Research Vehicle
Evaluation of the SMART obstacle detection system - Preliminary results

- To meet the main requirement for reliable mid (up to 200 m) and long range (up to 1000 m) obstacle detection ahead of the locomotive, a multi-baseline camera system:
  - C1 and C2 with shorter baseline (0.4m) and C1 and C3 with longer baseline (1.05m)
  - “chessboard” pattern-based camera calibration
Evaluation of the SMART obstacle detection system - Preliminary results

Image of the left camera of the scene in front of the IFS Research Vehicle

Visualisation of 3D scene points as detected by laser scanner and 3D scene points as reconstructed from vision data using stereo triangulation.
Evaluation of the SMART obstacle detection system-Preliminary results

Visualisation of 3D scene points as detected by laser scanner and 3D scene points as reconstructed from vision data using stereo triangulation

<table>
<thead>
<tr>
<th>Object distance with respect to vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ground truth</strong></td>
</tr>
<tr>
<td>55 m</td>
</tr>
</tbody>
</table>

**Sensor fusion results:**
- laser scanners have the advantage of direct and accurate measuring of distances to obstacles
- vision gives more detailed information about the surrounding environment
- the so-called region of interest (ROI) defined by vision-based scene reconstruction fused with the laser data points enabled finding of the important laser data points
Towards the integrated SMART obstacle detection system

- Field tests performed on Serbian railway test-site, 20\textsuperscript{th}-23\textsuperscript{rd} November 2017:
  - Straight rail tracks: 1300 m
  - Thermal camera in addition to stereo cameras and laser scanner
Towards the integrated SMART obstacle detection system

- Field tests performed on Serbian railway test-site, 20\textsuperscript{th}-23\textsuperscript{rd} November 2017:
  - Targets at 50 m, 100 m, 250 m, 500 m, 750 m
  - Stereo camera image: clearly visible targets at 50 m, 100 m
  - Laser point cloud: detected targets at 50 m, 100 m
  - Thermal camera image: all targets visible

\textit{Left stereo camera image} \hspace{1cm} \textit{Laser scanner point cloud} \hspace{1cm} \textit{Thermal camera image}
Object detection

Detection of a break in detected rail track
Region of Interest (ROI) detection
Object detection
Object detection

Visualisation of 3D scene points as detected by laser scanner and 3D scene points as reconstructed from the stereo camera system C1-C2 (with the shorter baseline)
Sensor fusion
Stereo vision + laser scanner

Visualisation of 3D scene points as detected by laser scanner and 3D scene points as reconstructed from the stereo camera system C1-C2 (with the shorter baseline)

<table>
<thead>
<tr>
<th>Object</th>
<th>Ground truth</th>
<th>Laser Scanner</th>
<th>C1-C2 stereo camera system</th>
<th>C1-C3 stereo camera system</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50 m</td>
<td>49.93 m</td>
<td>51.00 m</td>
<td>36.54 m</td>
</tr>
<tr>
<td>B</td>
<td>100 m</td>
<td>102.2 m</td>
<td>98.36 m</td>
<td>91.36 m</td>
</tr>
</tbody>
</table>

SMART Multi-Sensor OD System

Rail track reconstructed from vision

SMART Multi-Sensor OD System

Objects reconstructed from laser scanner

Objects reconstructed from Vision

Object A

Object B

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Thermal camera processing
Object detection + homography based distance estimation

- Field tests performed on Serbian railway test-site, 20\textsuperscript{th}-23\textsuperscript{rd} November 2017:

<table>
<thead>
<tr>
<th>Object Distance with respect to vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground truth</td>
</tr>
<tr>
<td>50 m</td>
</tr>
<tr>
<td>150 m</td>
</tr>
<tr>
<td>250 m</td>
</tr>
<tr>
<td>500 m</td>
</tr>
<tr>
<td>Estimated</td>
</tr>
<tr>
<td>51 m</td>
</tr>
<tr>
<td>155 m</td>
</tr>
<tr>
<td>271 m</td>
</tr>
<tr>
<td>550 m</td>
</tr>
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</table>
Integrated multi-sensory OD system

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

![CAD model of the sensor housing of the integrated ODS demonstrator](image)

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

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

![Diagram of multi-sensory OD system]

- 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
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, 27th-28th March 2018:
Integrated multi-sensory OD system

- RGB camera
  - Actual Scene
- Stereo camera
  - 3D point cloud
- Thermal camera
- LiDAR
  - 3D point cloud
- Night vision camera

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Integrated multi-sensory OD system

- RGB Camera Image Processing:
  - Rail tracks detection
  - Object recognition (classification)
Integrated multi-sensory OD system

- Thermal Camera Image Processing:
  - Rail tracks detection
  - Object detection and distance estimation

![Image of rail tracks detection and object detection with distance estimation]
Integrated multi-sensory OD system

- Night Vision Camera Image Processing:

  Rail tracks detection 800m
Integrated multi-sensory OD system

- SMART test vehicle, Serbia Kargo ŽS

Possible locations of the ODS demonstrator (grey rectangular).

Mounted ODS demonstrator

NEXT step, field tests with moving train, June 2018
ARCC-SMART collaboration in obstacle detection working stream

ARCC representatives visit to Serbia during field tests in March 2018

Future steps, to continue collaboration and perform joint tests
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:

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SMART Real-time Marshalling Yard Management System

• The SMART real-time marshalling yard management system will provide **optimization of available resources and planning of marshalling operations in order to decrease overall transport time and costs associated with cargo handling.**

• The yard management system will provide **real time data about resources available over standard data formats for connection to external network systems and shared usage of marshalling yards between different service providers.**
SMART Real-time Marshalling Yard Management System

• Web-based information system will be developed for visual representation of the marshalling yard configuration, provide manual and automated input of inbound and outbound train parameters

• The main goal is to provide advisory system for deviations in decision making process in order to take into account dispatchers’ experience while decreasing his subjective impact on the overall management system of local marshalling yard.
SMART Real-time Marshalling Yard Management System
SMART – ARCC cooperation and joint discussion
12-13\textsuperscript{th} June 2017

- Focus of activities should be the development of a “RTYM Optimization Module” that would be able to support the dispatcher’s decision making in case of any deviations from regular plans.
SMART Real-time Marshalling Yard Management System
SMART – ARCC cooperation and joint discussion
12-13th June 2017

- The module should take into account possible existing IT-solutions for yard management and from IM and RU, specific circumstances of each individual yard and the prospective availability of real-time data as well in the rail freight sector
SMART Real-time Marshalling Yard Management System Concept Solution

- Marshalling yard officials, dispatchers, operators
- External railway information system
- Local IT applications on marshaling yard

SMART RTYM

- Communication
- Integration
- Data input sub module
- Visual and planning module
- Optimization module
- Data output sub module

Database

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SMART Real-time Marshalling Yard Management System Concept Solution

Inputs

Existing IT applications

SMART RTMY

Outputs

There are no deviations
There are deviations

Checking deviation
Analysis of causes
Analysis of consequences
Required decisions

Inputs
List of deviation criteria
List of deviation causes and consequences

Outputs
List of decision consequences
SMART Real-time Marshalling Yard Management System

3 WPs

• Analysis, requirements and specification of a real-time marshalling yard management system

• Modelling, real time simulation and optimization of marshalling process

• Development of Web-based information system for supervision and management of marshalling yards
SMART Real-time Marshalling Yard Management System

- Analysis, requirements and specification of a real-time marshalling yard management system – Niš-Popovac (Serbia)
SMART Real-time Marshalling Yard Management System

• Analysis, requirements and specification of a real-time marshalling yard management system – Karnobat (Bulgaria)
SMART Real-time Marshalling Yard Management System

• Analysis, requirements and specification of a real-time marshalling yard management system

List of requirements for RTYMS

<table>
<thead>
<tr>
<th>Dynamic parameters</th>
<th>Static parameters</th>
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<tbody>
<tr>
<td><strong>Data flow:</strong></td>
<td><strong>Yard connections:</strong></td>
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<tr>
<td>Timetable</td>
<td>Number of railway</td>
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<tr>
<td>Train type</td>
<td>traffic directions</td>
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<tr>
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<tr>
<td>starting station</td>
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<tr>
<td>Train mass in tones</td>
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<td>Train length in</td>
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<tr>
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<td>Train composition</td>
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</tr>
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<tr>
<td><strong>Restrictions and</strong></td>
<td><strong>Layout data:</strong></td>
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<tr>
<td><strong>deviations:</strong></td>
<td>Groups of sidings on</td>
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<td>the marshaling yard</td>
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<tr>
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<tr>
<td>of incoming trains</td>
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<tr>
<td>Acceptance of delay</td>
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<td>from outgoing trains</td>
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<td>in order to ensure</td>
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<td><strong>others parameters:</strong></td>
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<tr>
<td></td>
<td>Number and type of</td>
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<td>hump retarders...</td>
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SMART Real-time Marshalling Yard Management System

- Forming database of EU marshalling yards

Niš (Serbia), Karnobat (Bulgaria), Poduene (Bulgaria), Munich Nord (Germany), Manheim (Germany), Hallsberg (Sweden)
SMART Real-time Marshalling Yard Management System

- Main data flow
SMART Real-time Marshalling Yard Management System

Deviations of decision making processes in MY

- Deviations of the incoming train – later (delay) or earlier than timetable plan
- Deviations of the outgoing train - later (delay) or earlier than timetable plan
- Deviations in personal resources – lack of train driver or other staff for operations in MY
- Deviations in individual wagons modification
- Unexpected repair or breakage of sections of rail line
- Unexpected repair or breakage of wagons
- Deviations or incorrect weight of incoming trains or wagons
- Priorities in cases of congested infrastructure or other priority policies
- Extraordinary requests
- Not defined deviations
SMART Real-time Marshalling Yard Management System

Deviations of decision making processes in MY

10 selected deviations in decision making processes
SMART Real-time Marshalling Yard Management System

1. Deviation of the incoming trains from the plan (delay or arriving earlier).

- Actors and roles
  
  **Dispatcher**
  
  **Yard operator**

- Information about timetable deviations of train runs
- Information about trains approaching the yard

- Ad-hoc changing sequence/prioritisation of yard operations

- Use case

  **MY Yard**
  Incomming deviation (delay)

  - Change sequence
  - Coordinate yard staff
  - Prioritise yard operations
  - Provide info

  **Dispatcher**

  Request info

  **Yard operator**

  Info provided

  **Change sequence**

  Sequence changed

  **Coordinate staff activities**

  New instructions obtained

  **Application**

  **Yard staff**
SMART Real-time Marshalling Yard Management System

- Development of Web-based information system for supervision and management of marshalling yards

Diagram of database structure (logical schema) of Marshalling yard data

Real wagon data from SMART database

Data for sidings in SMART database
SMART Real-time Marshalling Yard Management System

• Visualization and planning module

Data flow of Visualization and planning module

Component diagram of Visualization and planning module

Class diagram of Visualization and planning module
SMART Real-time Marshalling Yard Management System

• Optimization module

3 optimization criterias are selected:
- Time
- Energy consumption
- Cost
SMART Real-time Marshalling Yard Management System

- Application is created in such manner that it can work as online web application and in offline mode, as standard desktop application.
- Both modules have Front End part oriented to the user, and Back End part which contains business logic of the application.
- Marshalling yard data is inserted and organized in relation manner, through RDBMS (Relation Database Management System) – MySQL database is chosen as preferable storage system.
- Front End is realized in JavaScript (JS) and supporting libraries. Back End is based on Java or Python programming languages, or on combination of both
SMART Real-time Marshalling Yard Management System
SMART Real-time Marshalling Yard Management System
SMART Real-time Marshalling Yard Management System
Simulation of incoming train - Wagon malfunction
SMART Real-time Marshalling Yard Management System

Simulation of incoming train - Wagon malfunction

Positioned trains

Marshalling yard Popovac

Wagon malfunction

Solution

SMARTVIZ

Current Timetable
Infrastructure
General Data

Simulations
- Wagon malfunction
- Lack of People
- Train delay

Proposed solution
Fix it!

Current trains:
- Incoming: 2
- Outgoing: 4
- On Hold: 1

Current wagons:
- Distributed: 124
- Broken: 5
- On Service: 7

People:
- Active: 50
- Trains: 10
- Out: 7

Possible deviations:
- Train delay: 3
- Lack of workers: 2
- Locomotive regular service: 1

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SMART Real-time Marshalling Yard Management System

Simulation of incoming train – Proposed solution

Positioned wagons

Repair position

**SMARTviz**
- Marshall Yard schema
- Current Timetable
- Infrastructure
- General Data

**Simulations**
- Wagon malfunction
- Lack of people
- Train delay

**Proposed solution**

**Current trains**
- Incoming: 2
- Outgoing: 4
- On hold: 1

**Current wagons**
- Distributed: 10
- Broken: 5
- On service: 7

**People**
- Active: 60
- Teams: 10
- Out: 7

**Possible deviations**
- Train delay: 3
- Lack of workers: 2
- Locomotive regular service: 1

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SMART Real-time Marshalling Yard Management System

NEXT STEPS

• Selected and tested optimization algorithms – July 2018

• Initial testing of pilot application in MY Karnobat (Bulgaria) and MY Niš (Serbia) – October 2018
Thank you for your attention!

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