Shift Freight to Rail: Midterm Event for S2R Projects from Call 2015-2016 & Final Event for Smart-Rail Lighthouse Project
Vienna, 18 April 2018

SMART
SMart Automation of Rail Transport

Ristić-Durrant Danijela, Simonović Miloš

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Overview

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

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SMART project ID card

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

- Project reference: 730836 — SMART — H2020-S2RJU-2015-01/H2020-S2RJU-OC-2015-01-2
- Total budget: 999.598 €
- Project start: 1st October 2016; Duration: 36 months
- Consortium: 5 participants from 3 European countries
- **Collaboration: ARCC**

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SMART consortium

Project coordinator, Sensor-based obstacle detection

iat

Universität Bremen

Real-time marshalling yards management; Obstacle detection

University of Niš

Real-time marshalling yards management

Technical University of Sofia
We succeed!

Evaluation; Real-time yard management

IFS RWTH AACHEN UNIVERSITY

Obstacle detection system prototype; Night vision

HARDER digital SOVA

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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

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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**

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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**

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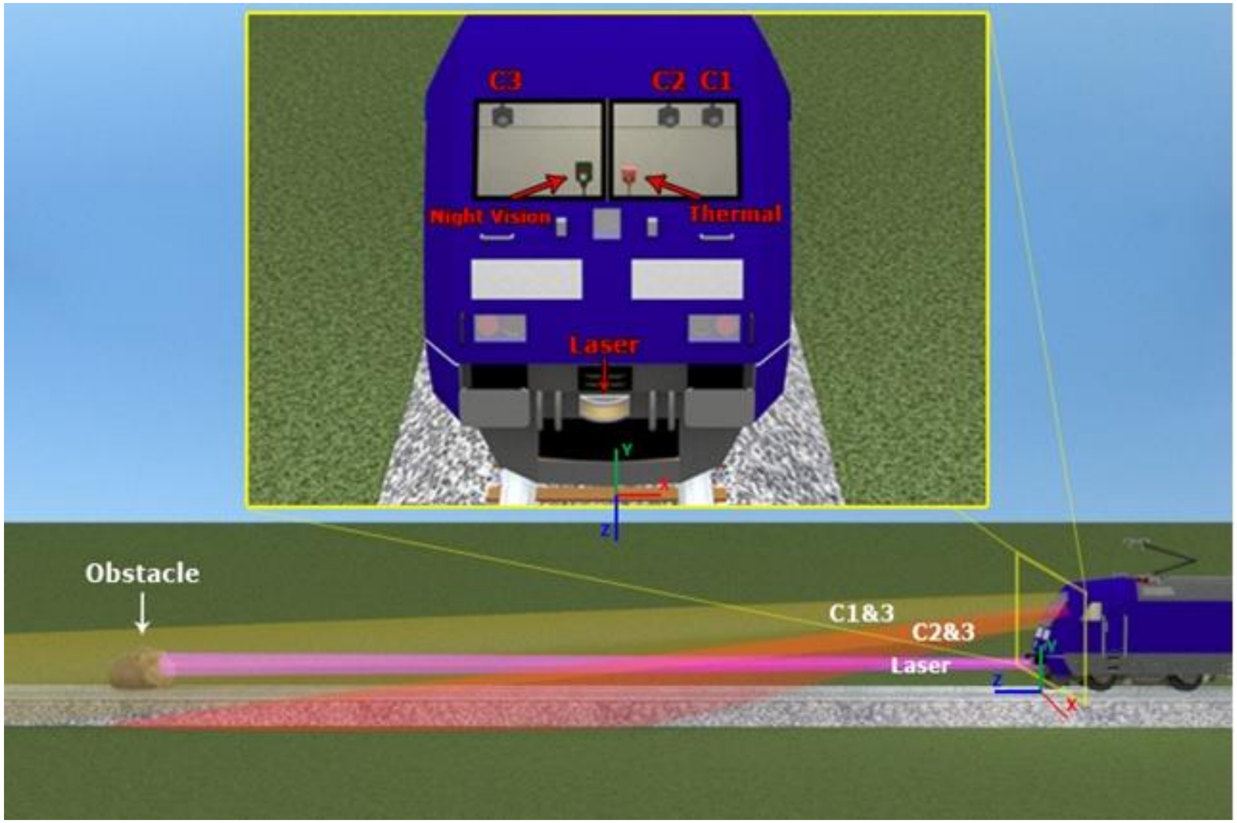
Concept of the SMART multi-sensor obstacle detection system



- Sensor Fusion:
  - ✓ two pairs of stereo cameras C1-C3; C1-C2
  - ✓ Thermal vision
  - ✓ Night vision
  - ✓ Laser scanner

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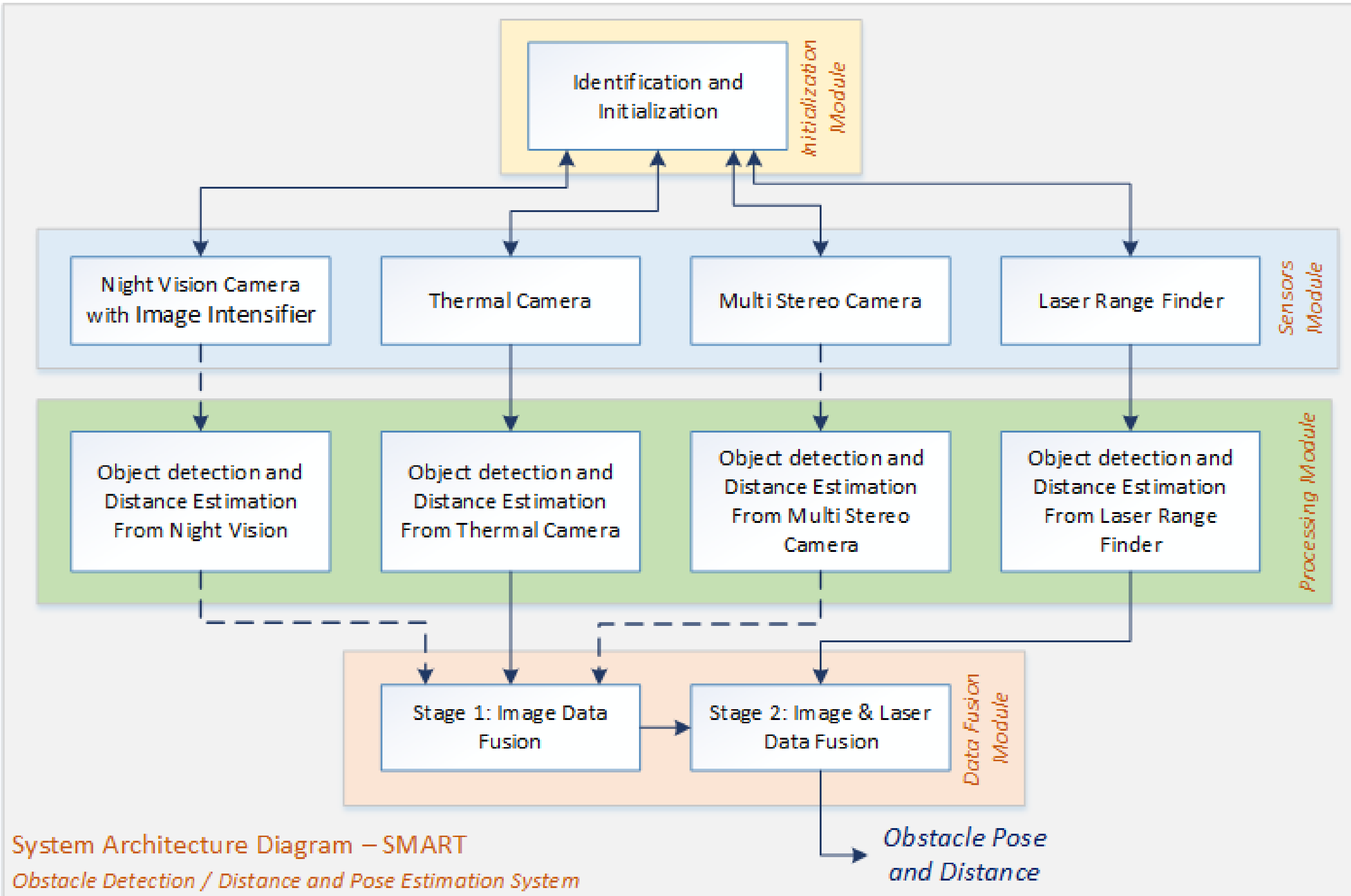
Concept of the SMART multi-sensor obstacle detection system



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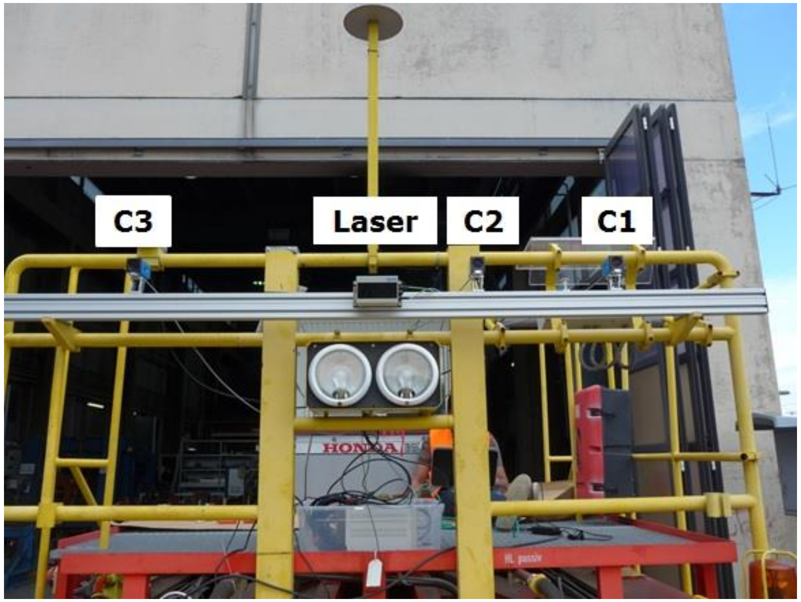
Evaluation of the SMART obstacle detection system

- 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

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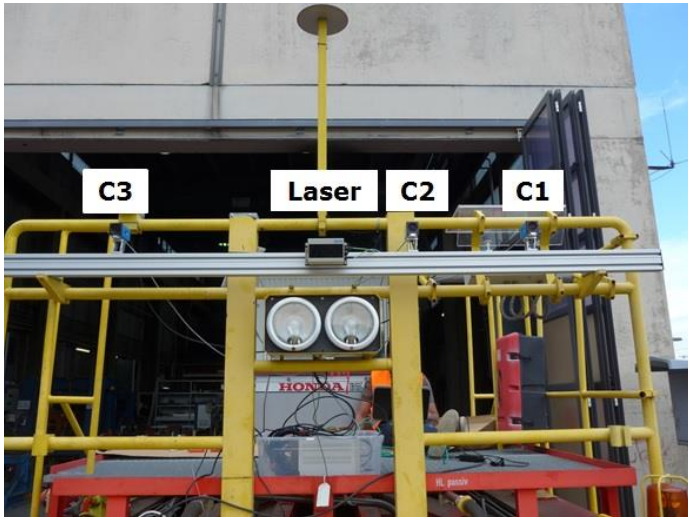
Evaluation of the SMART obstacle detection system-Preliminary results

- 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



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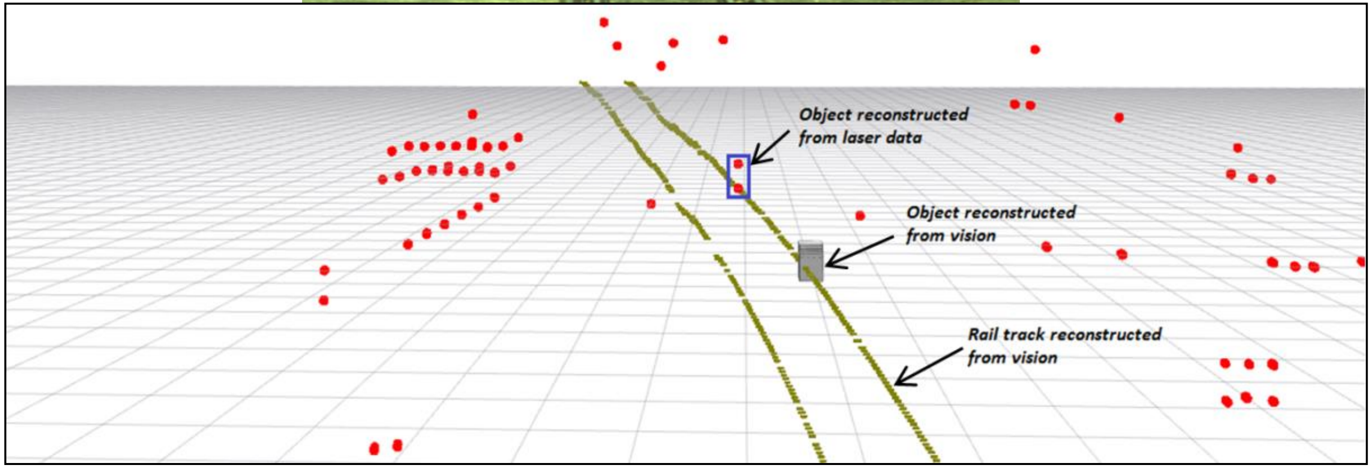
Evaluation of the SMART obstacle detection system-Preliminary results

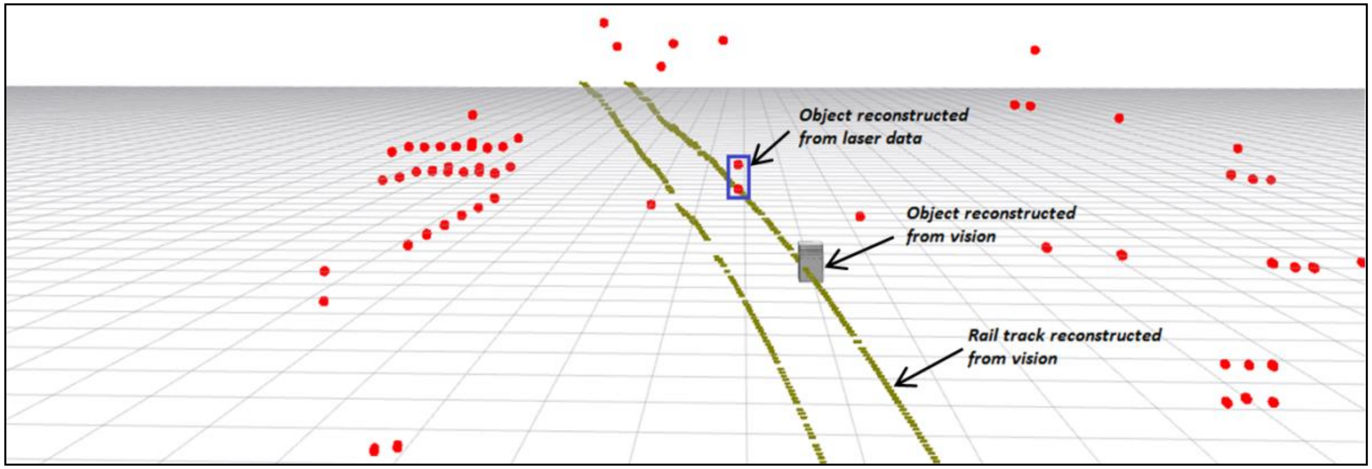
Image of the left camera of the scene in front of the IFS Research Vehicle



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



Object distance with respect to vehicle		
Ground truth	Laser Scanner	C1-C2 stereo camera system
55 m	54.947 m	51.278 m

- **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

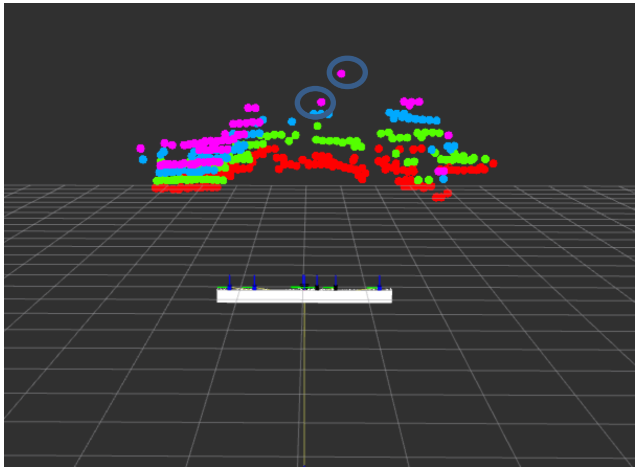
Towards the integrated SMART obstacle detection system

- Field tests performed on Serbian railway test-site, 20th-23rd **November 2017**:
  - Straight rail tracks: 1300 m
  - Thermal camera in addition to stereo cameras and laser scanner

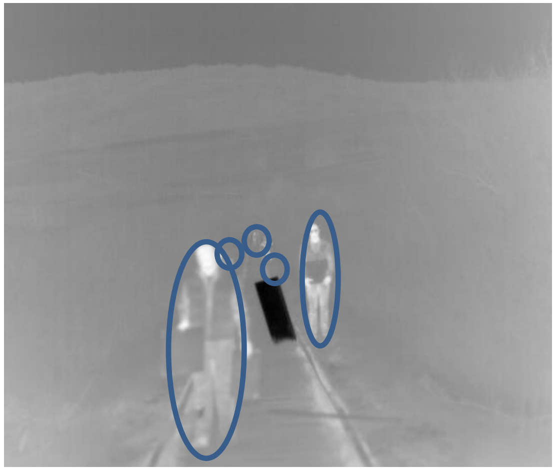
Towards the integrated SMART obstacle detection system

- Field tests performed on Serbian railway test-site, 20th-23rd **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

Left stereo camera image

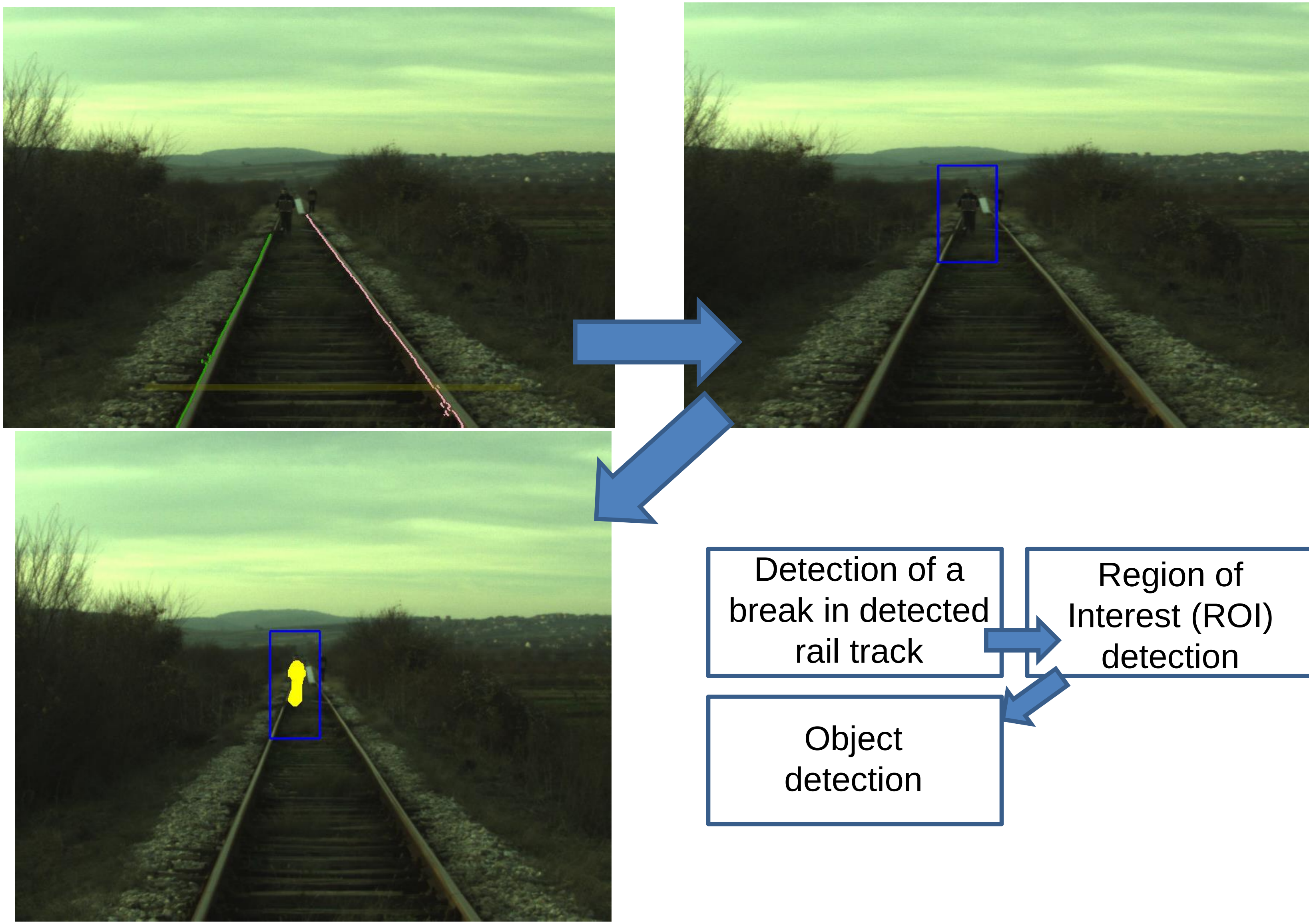


Laser scanner point cloud

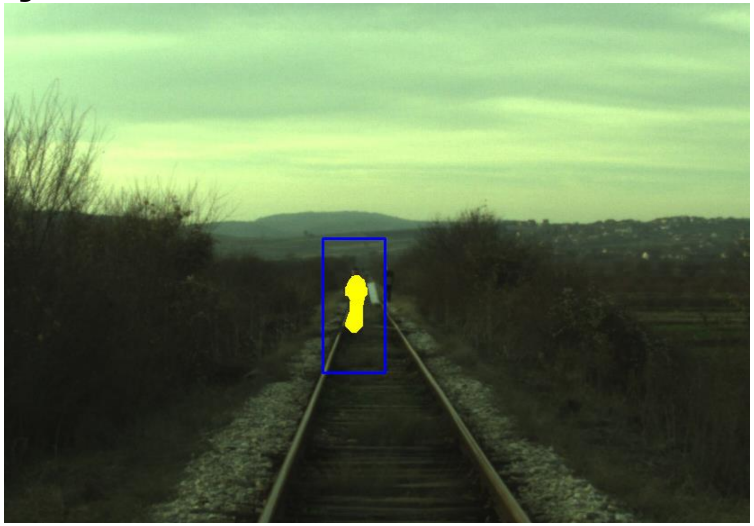


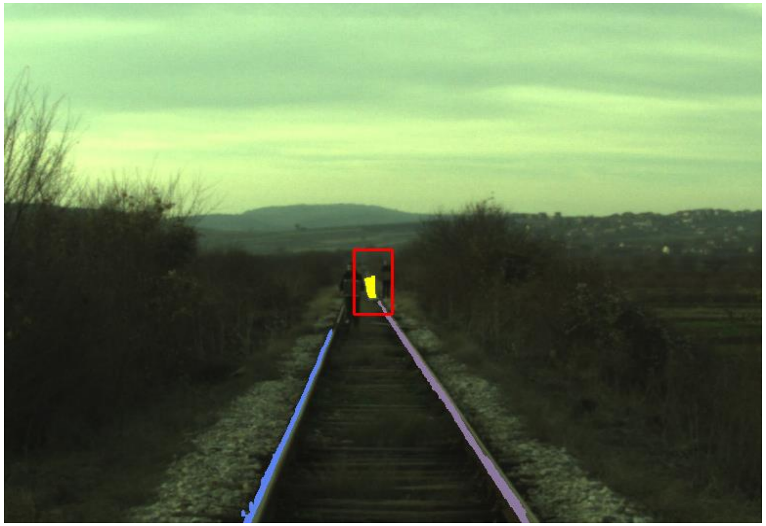
Thermal camera image

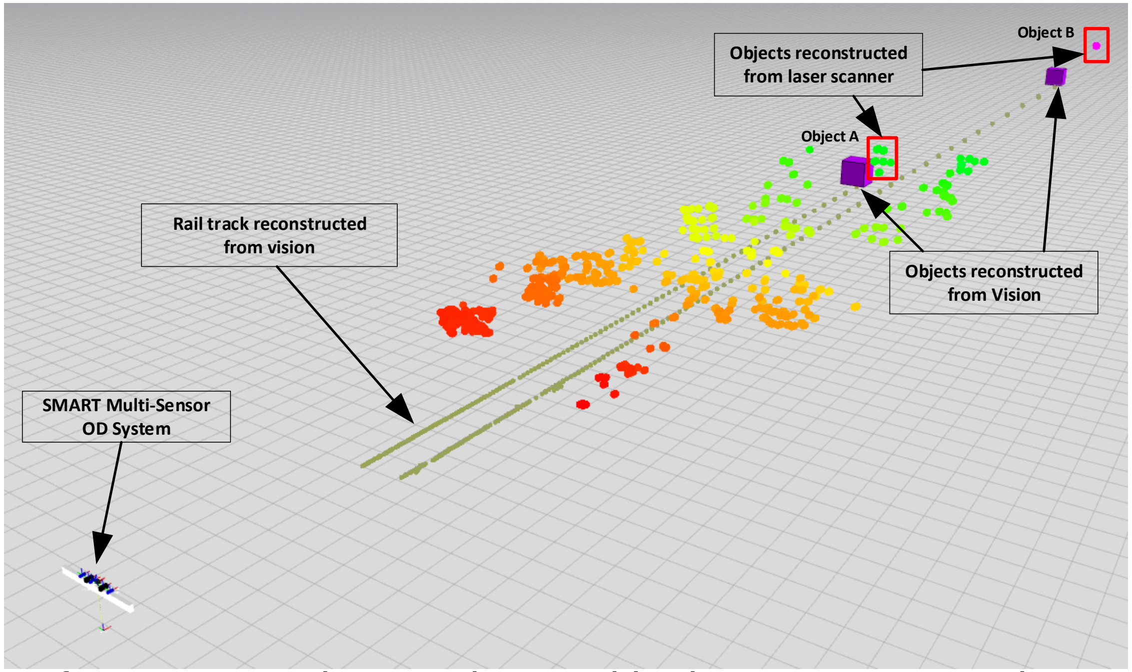
Object detection



Object detection



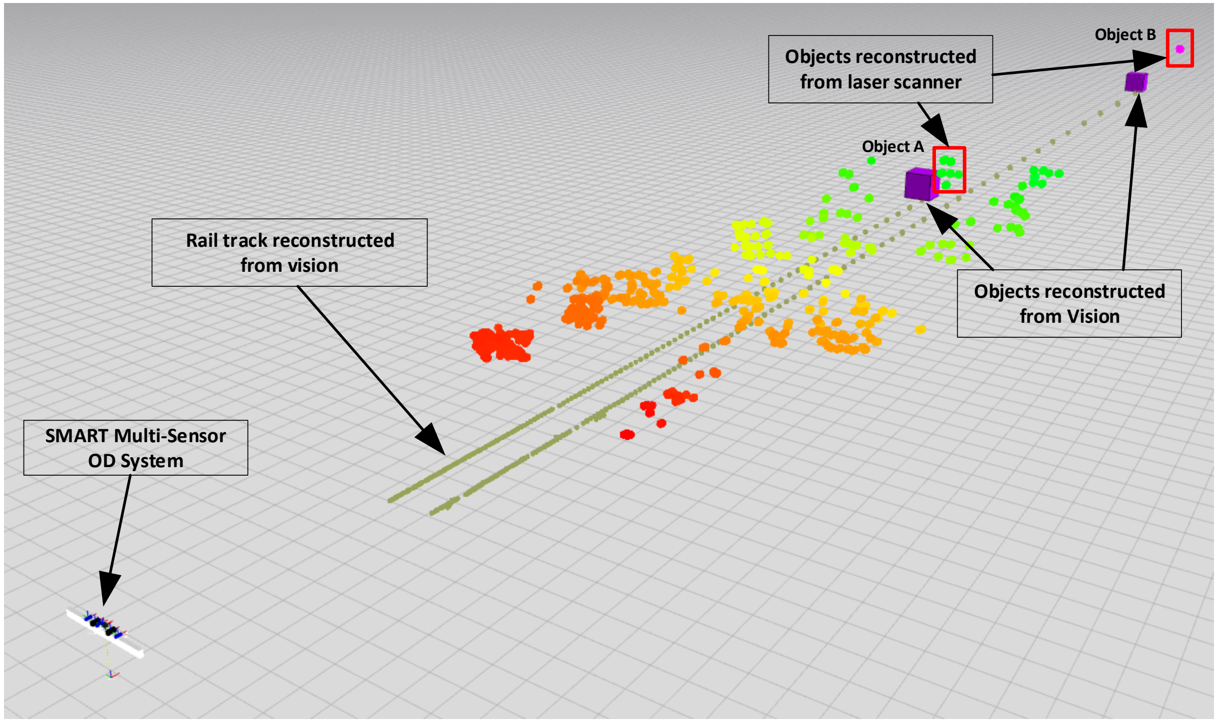




Visualisation of 3D scene points as detected by laser scanner and 3D scene points as reconstructed from the stereo camera system C1-C2 (with the shorter baseline)

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)



Object Distance respect to train				
Object	Ground truth	Laser Scanner	C1-C2 stereo camera system	C1-C3 stereo camera system
A	50 m	49.93 m	51.00 m	36.54 m
B	100 m	102.2 m	98.36 m	91.36 m

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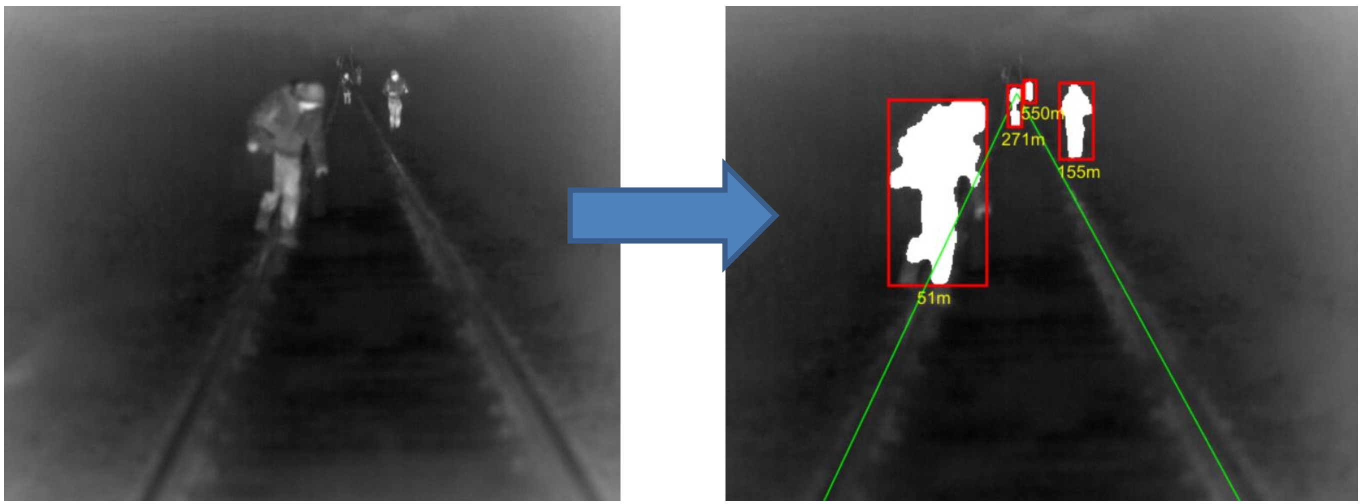
Thermal camera processing
Object detection + homography based distance estimation

- Field tests performed on Serbian railway test-site, 20th-23rd **November 2017**:



Object Distance with respect to vehicle				
Ground truth	50 m	150 m	250 m	500 m
Estimated	51 m	155 m	271 m	550 m

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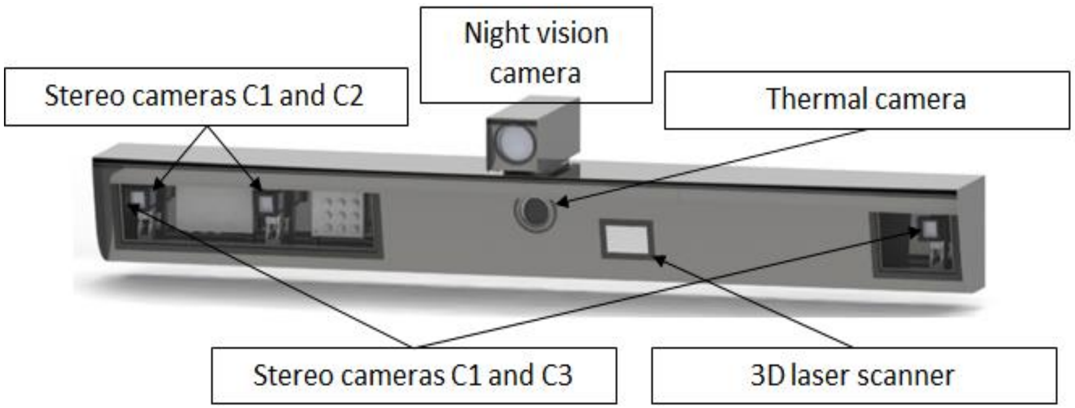
Integrated multi-sensory OD system

- 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

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

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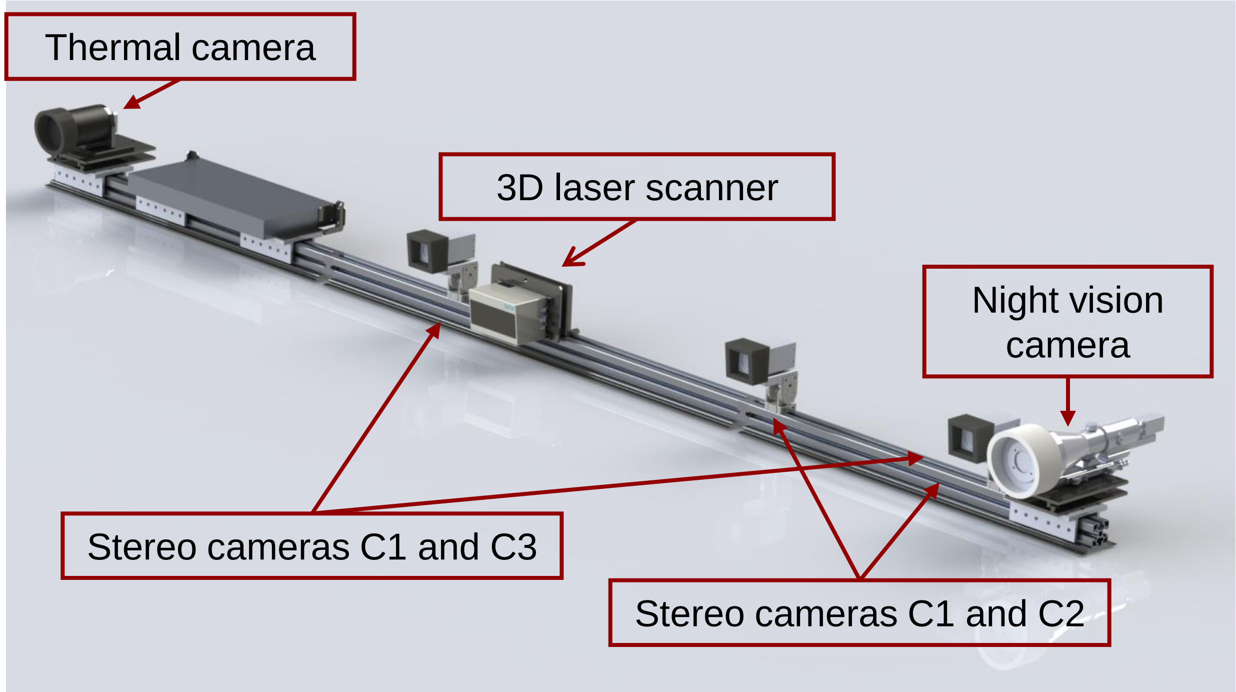
Integrated multi-sensory OD system

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



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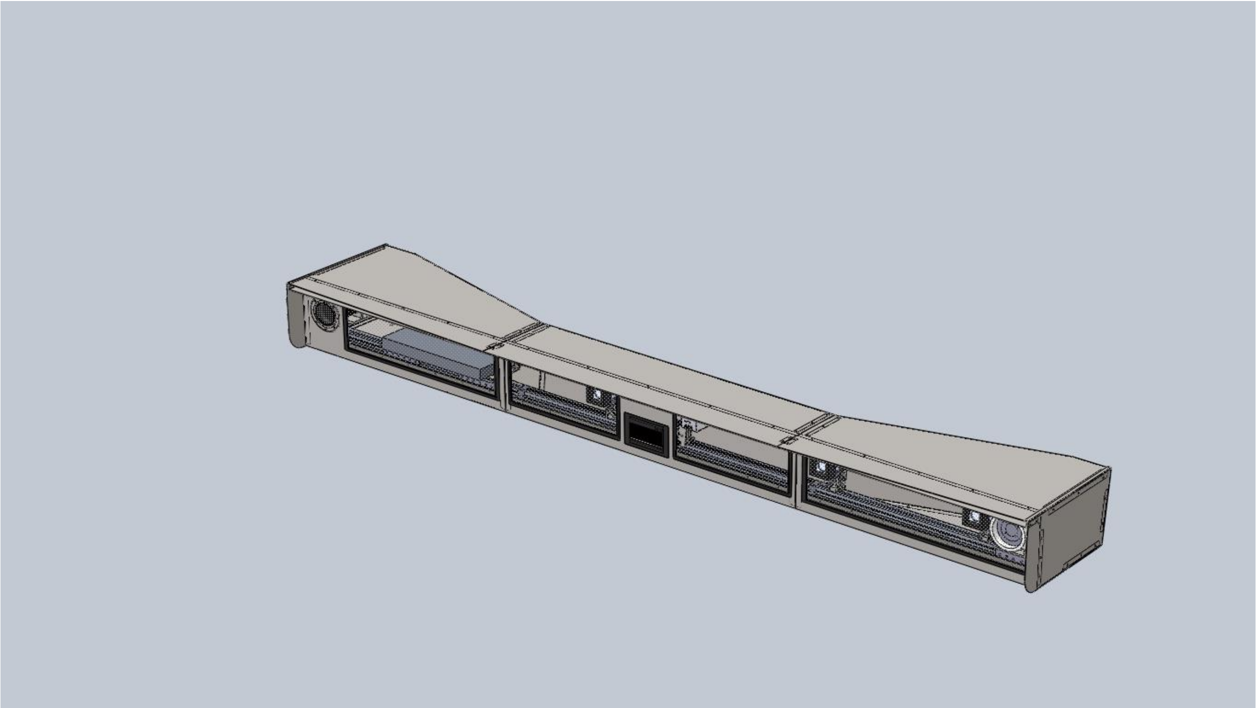
- Final design of sensors housing which will enable mounting of the OD system on different test vehicles



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Integrated multi-sensory OD system

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

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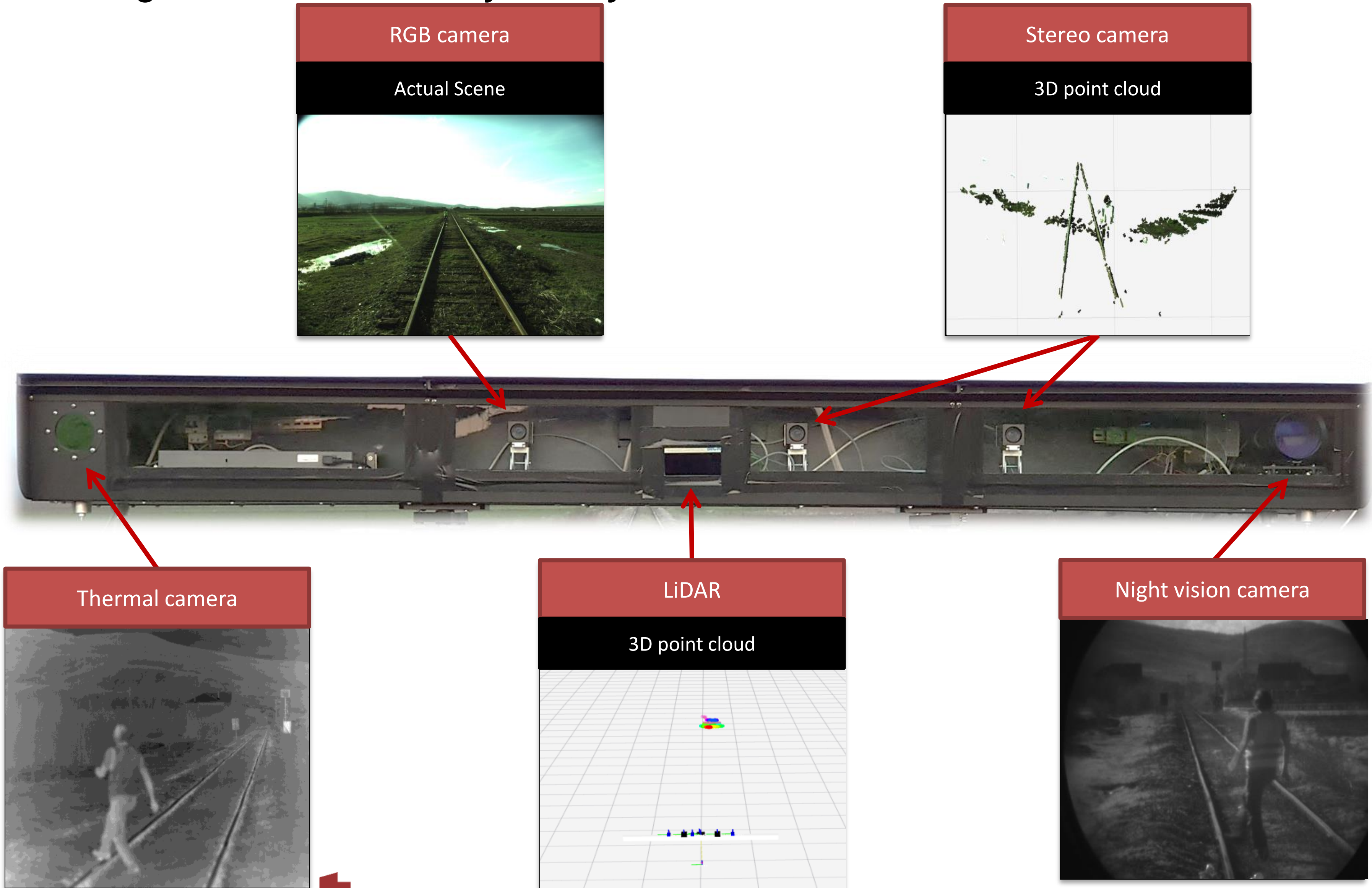
Integrated multi-sensory OD system

- 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



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Integrated multi-sensory OD system

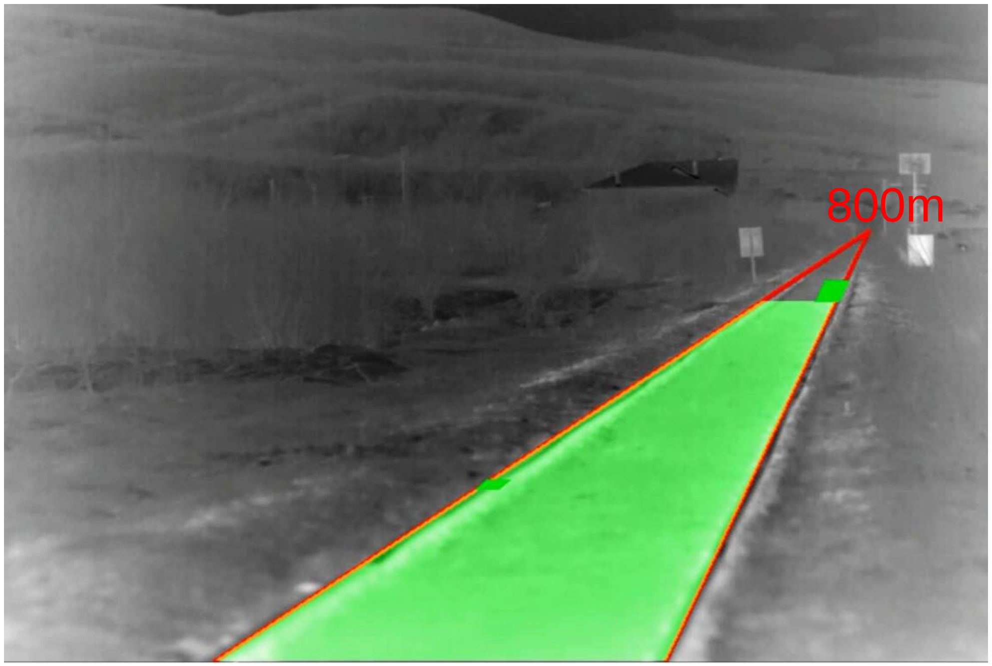
- RGB Camera Image Processing:

Rail tracks detection

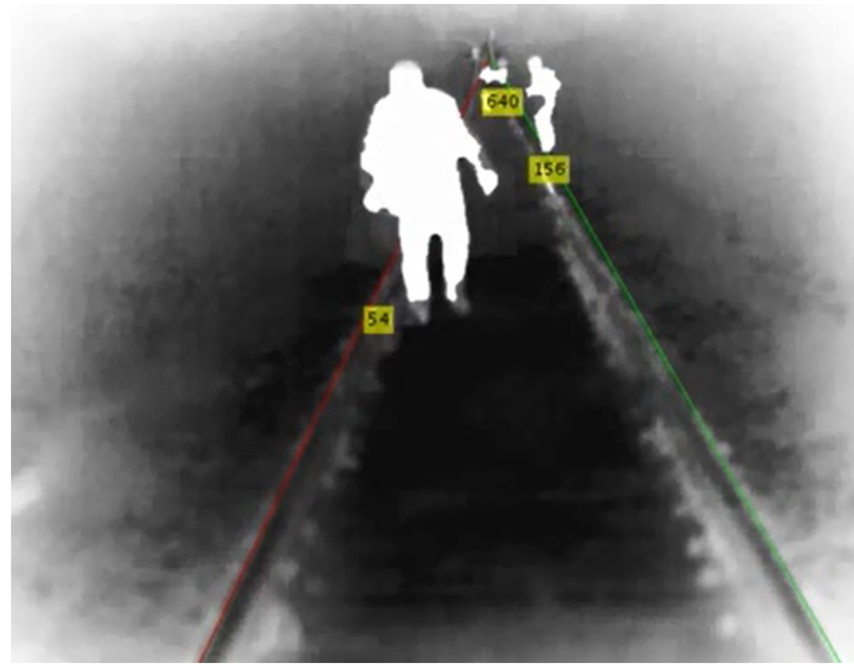
Object recognition (classification)

Integrated multi-sensory OD system

- Thermal Camera Image Processing:



Rail tracks detection



Object detection and distance estimation

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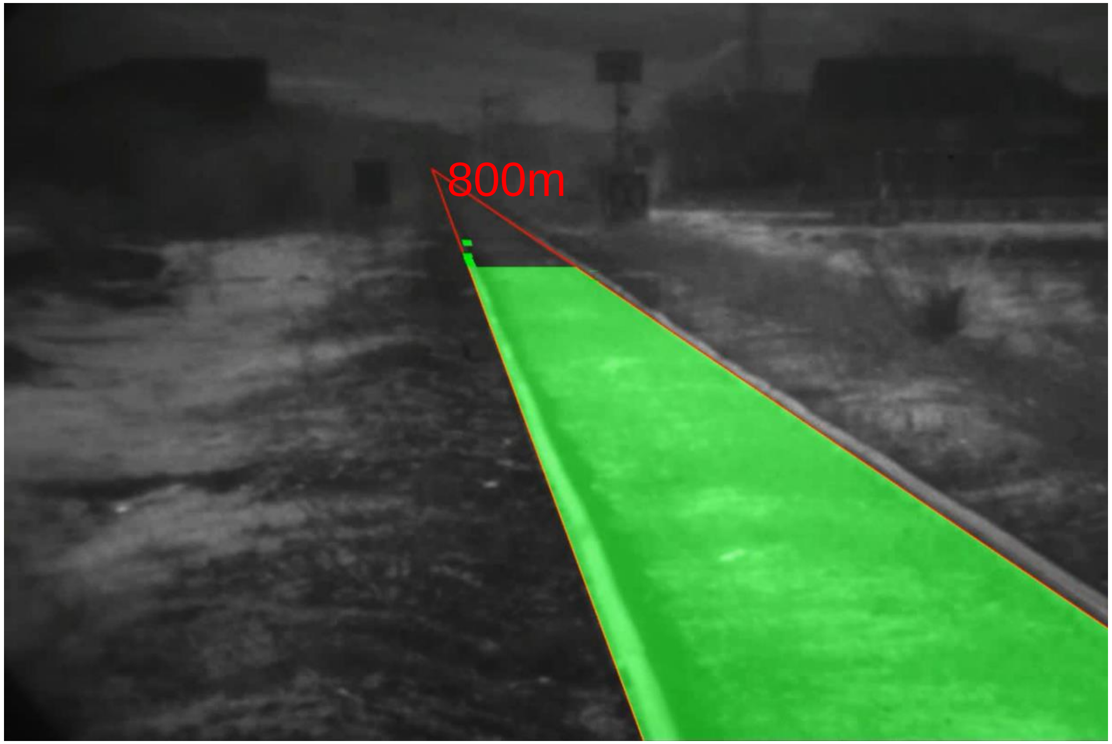
Integrated multi-sensory OD system

- Night Vision Camera Image Processing:



Rail tracks detection

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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

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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

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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.**

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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.

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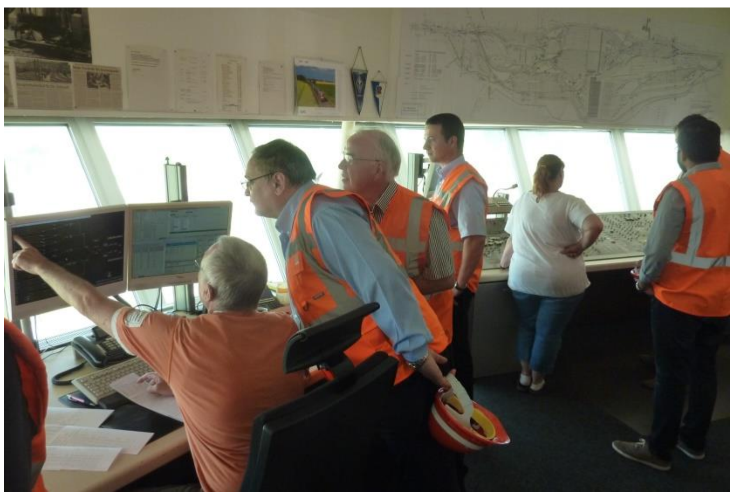
SMART Real-time Marshalling Yard Management System
SMART – ARCC cooperation and joint discussion
12-13th June 2017

- 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**.



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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**

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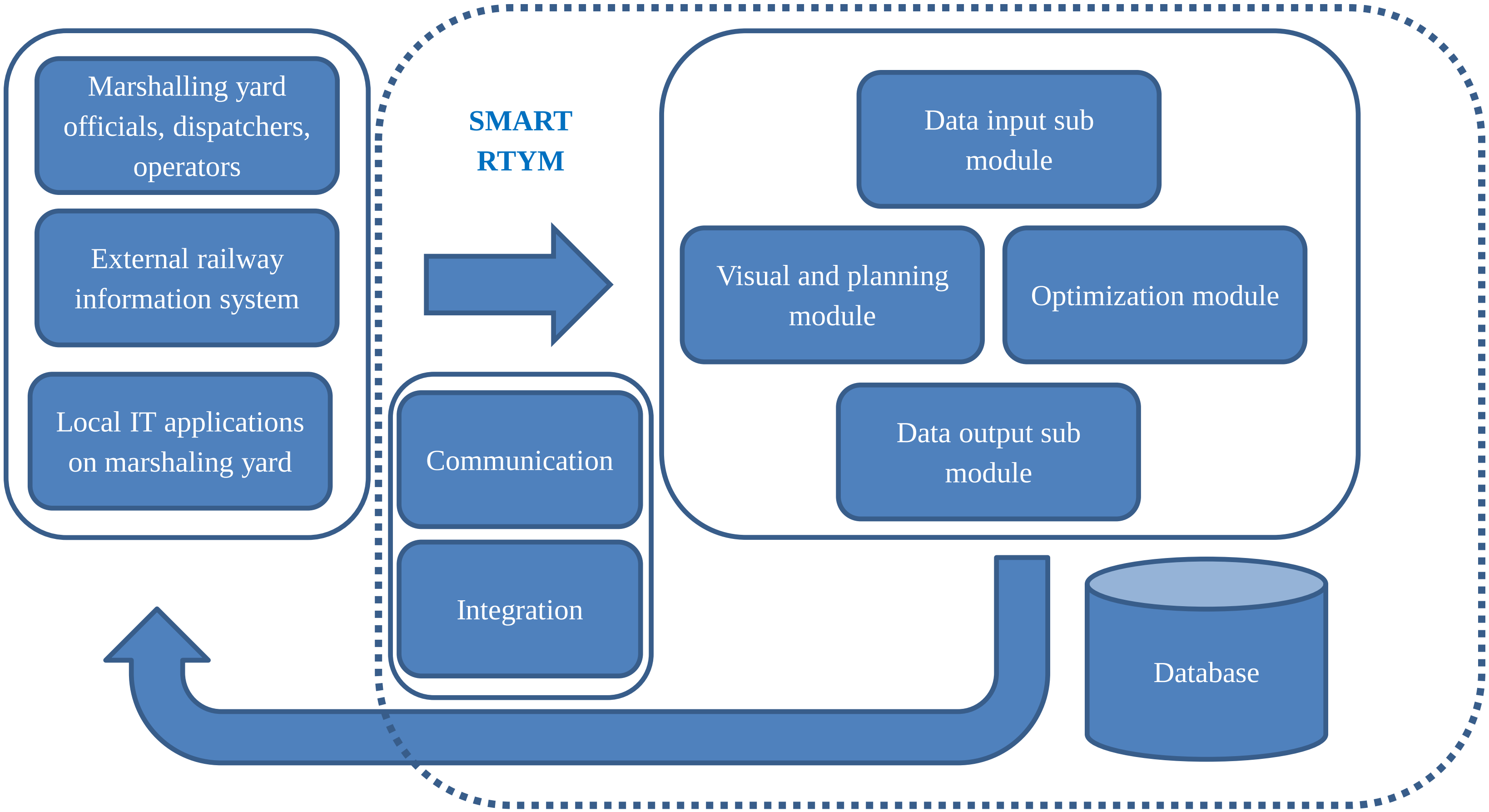
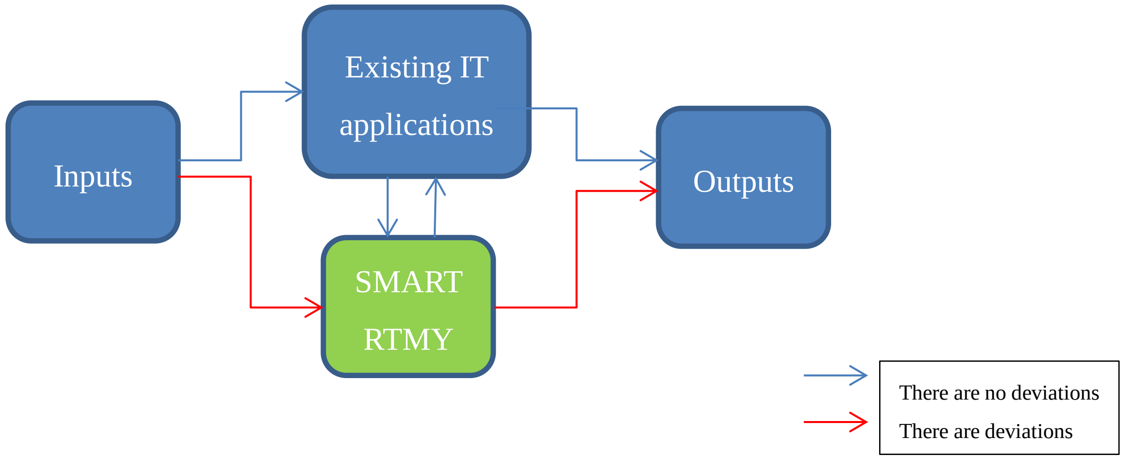
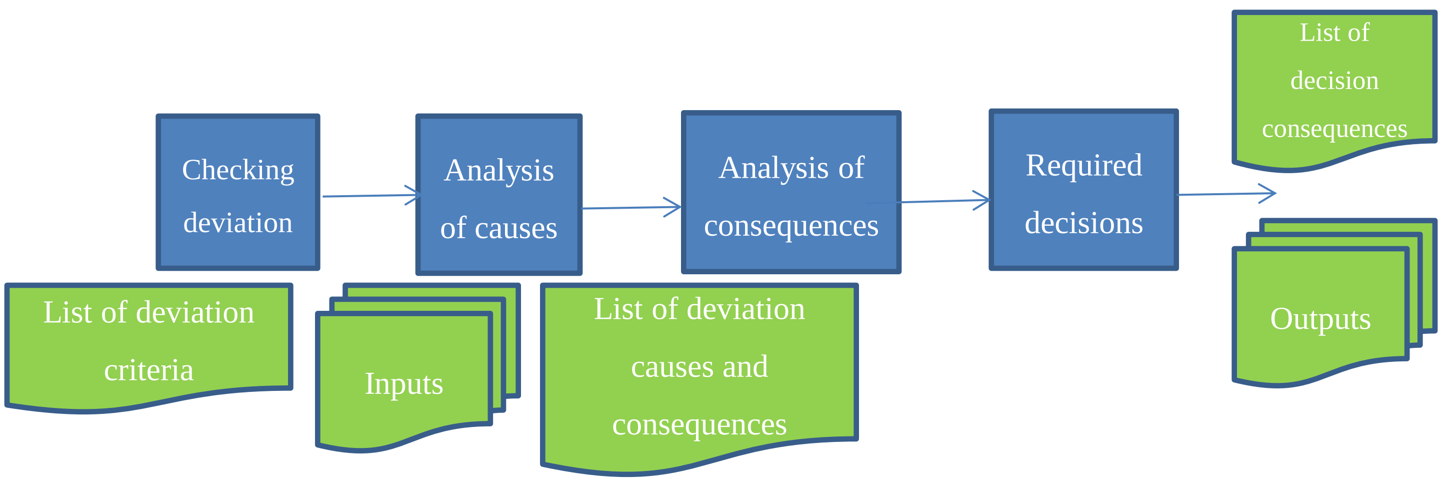
SMART Real-time Marshalling Yard Management System Concept Solution



SMART Real-time Marshalling Yard Management System Concept Solution





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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

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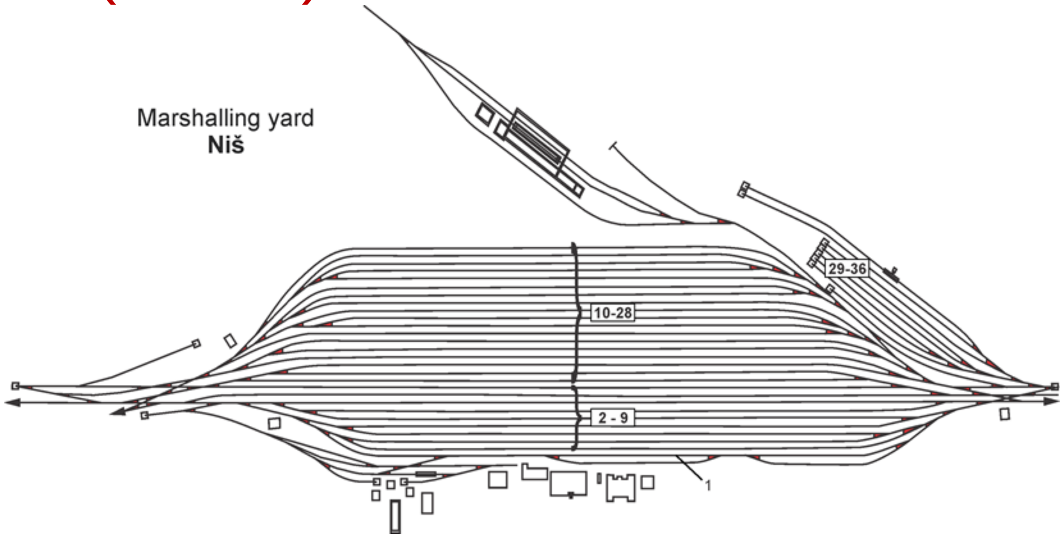
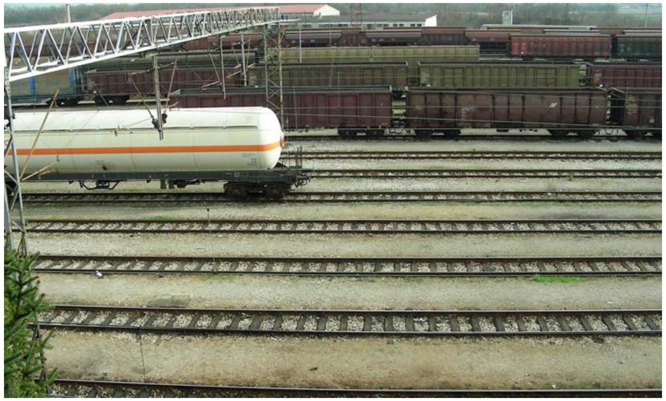
SMART Real-time Marshalling Yard Management System

- Analysis, requirements and specification of a real-time marshalling yard management system – Niš-Popovac (Serbia)





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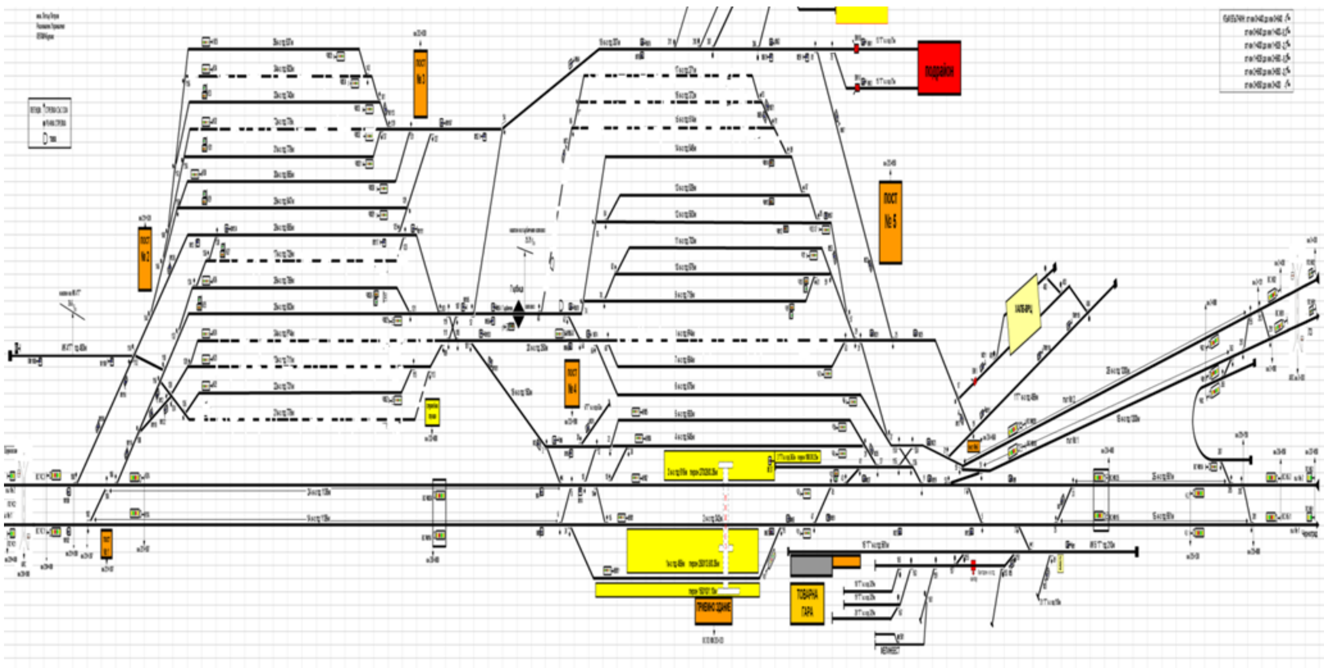
SMART Real-time Marshalling Yard Management System

- 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

Dynamic parameters

Data flow:
Timetable
Train type
Train number
Dispatch time of starting station
Name of starting station
Train mass in tones
Train weight per axle
Train length in meter
Train composition
Wagon series and subseries…

Restrictions and deviations:
Temporary non-working resources like yard connections, layout etc…
Changes of the planned sequence of incoming trains
Acceptance of delay from outgoing trains in order to ensure wagon transit…

Static parameters

Yard connections:
Number of railway traffic directions
Limitations of railway traffic direction

Layout data:
Groups of sidings on the marshaling yard
Number of tracks per group
Sidings purpose…

Operative times:
Mean time for each technological activity

Equipment and others parameters:
Number and type of shunting locomotives
Number and type of hump retarders…

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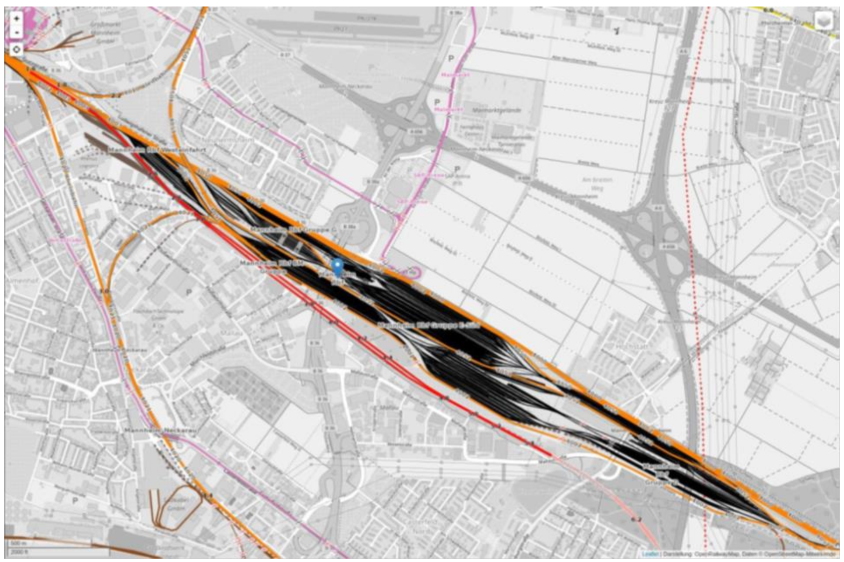
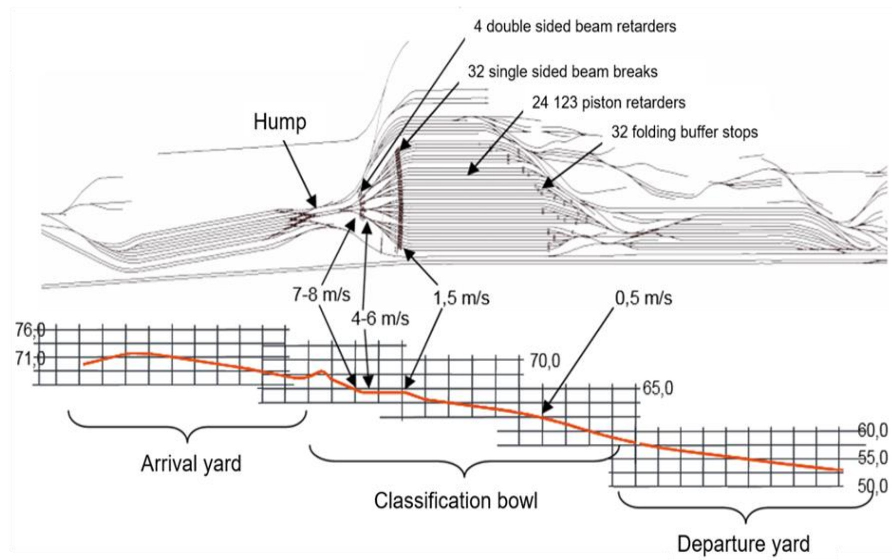
SMART Real-time Marshalling Yard Management System

- Forming database of EU marshalling yards

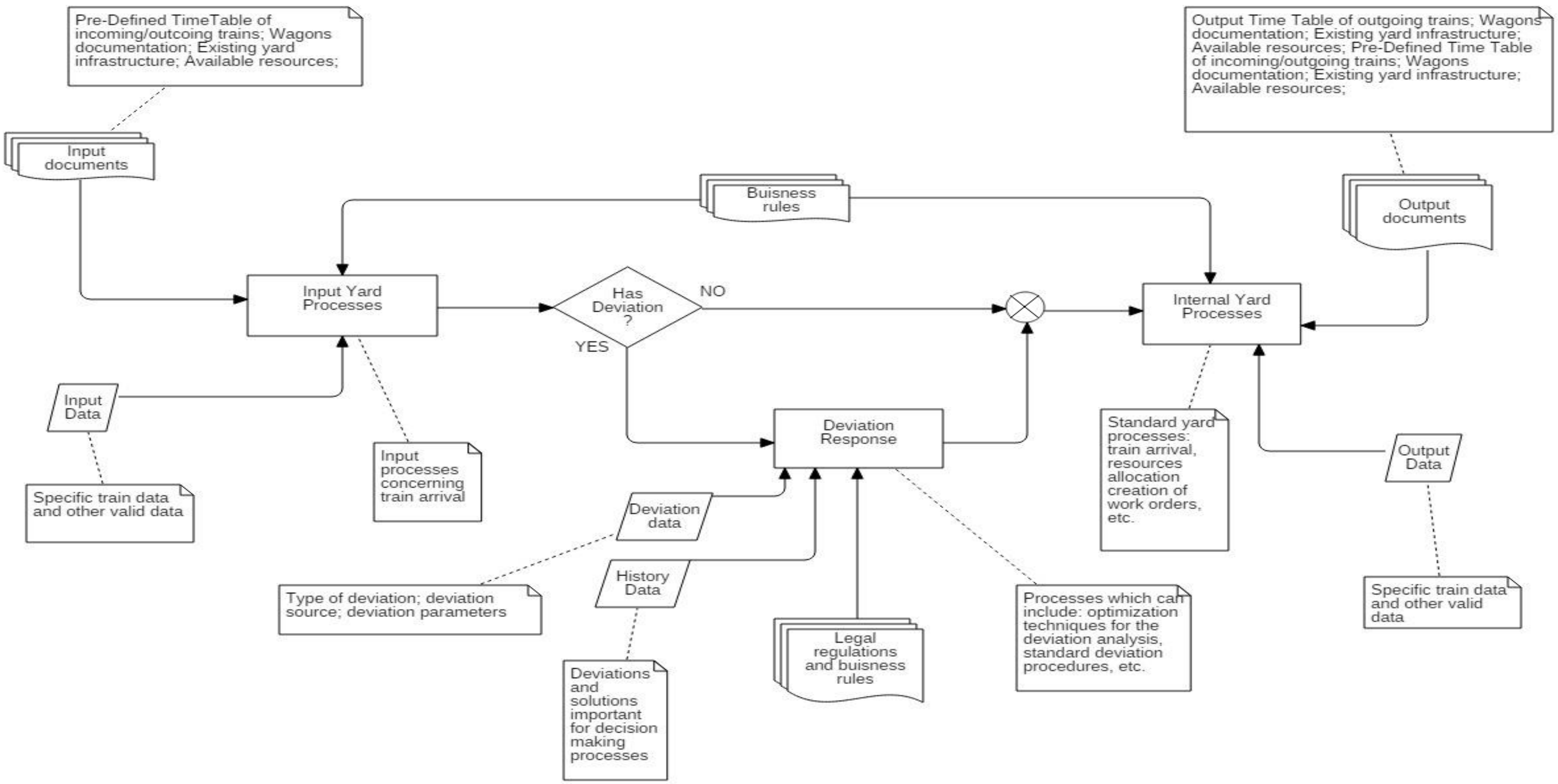
Niš (Serbia), Karnobat (Bulgaria), Poduene (Bulgaria) Munich Nord (Germany), Manheim (Germany), Hallsberg (Sweden)





SMART Real-time Marshalling Yard Management System

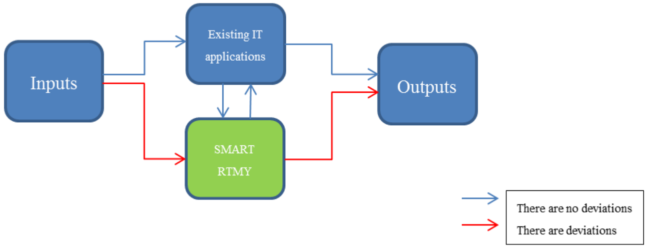
- Main data flow



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



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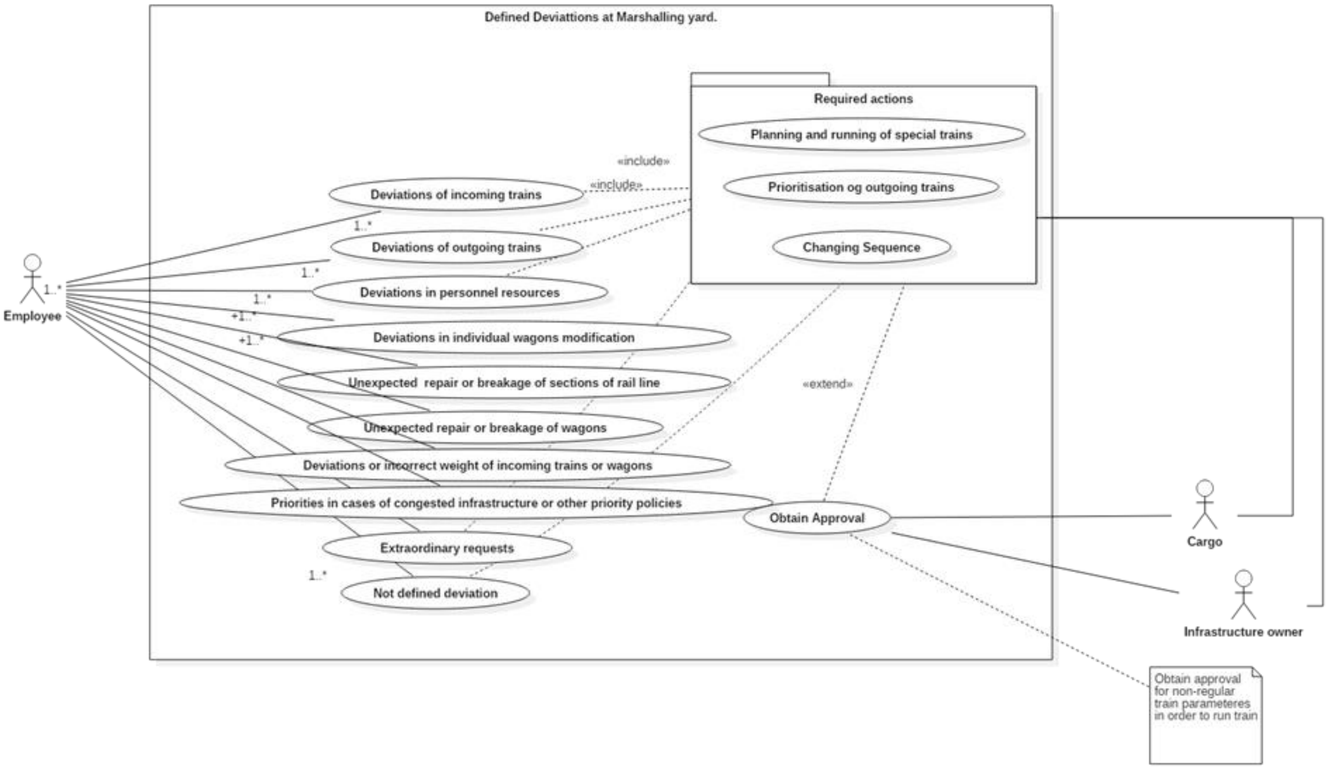
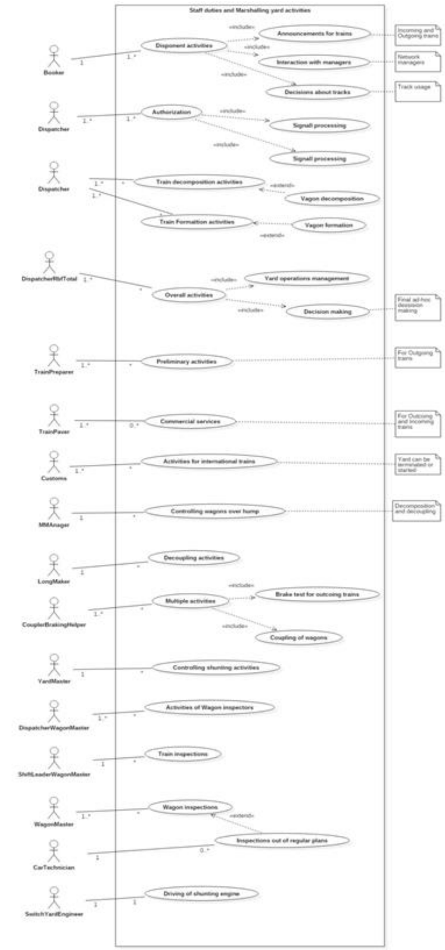
SMART Real-time Marshalling Yard Management System

Deviations of decision making processes in MY



Roles and responsibilities



10 selected deviations in decision making processes

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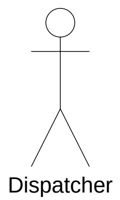
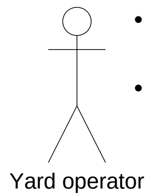
SMART Real-time Marshalling Yard Management System

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

- Actors and roles

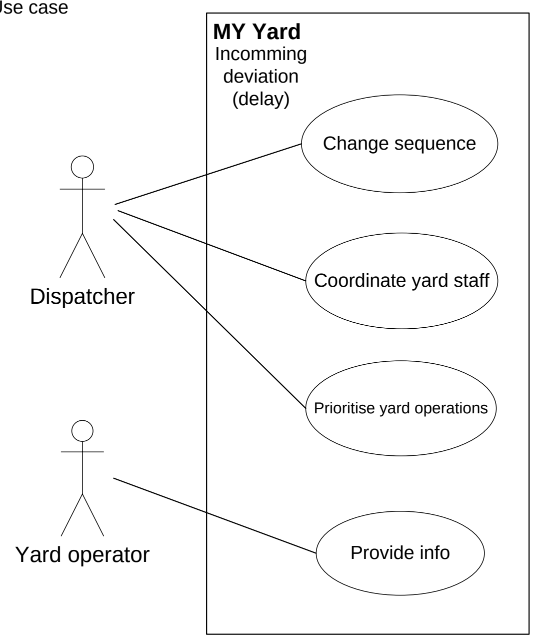


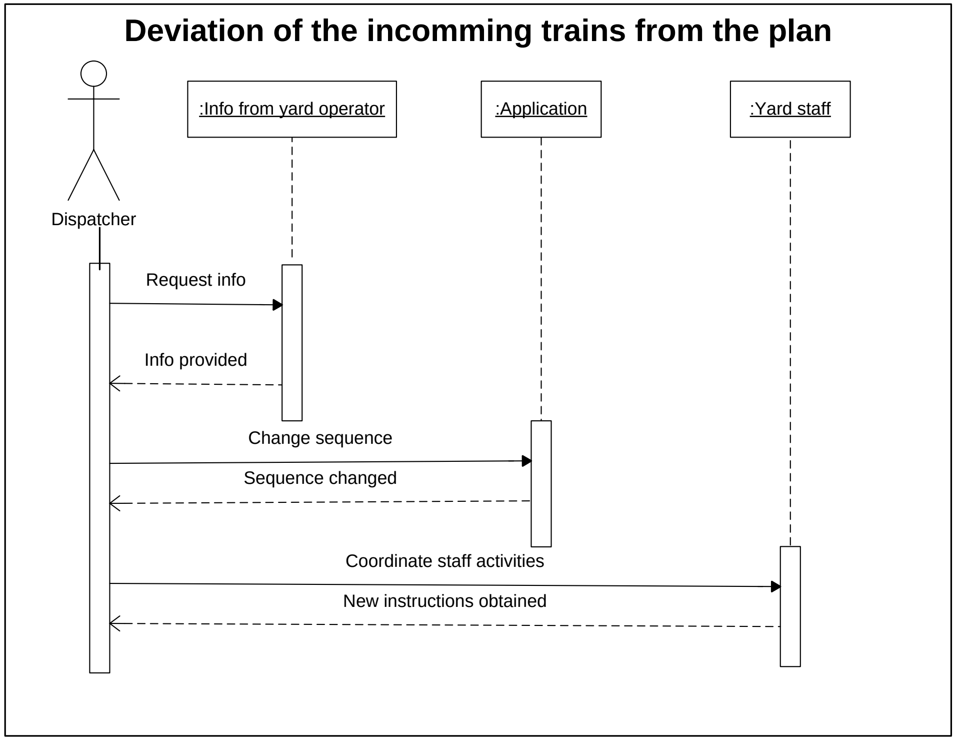
- Ad-hoc changing sequence/ prioritisation of yard operations



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

- Use case





SMART Real-time Marshalling Yard Management System

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

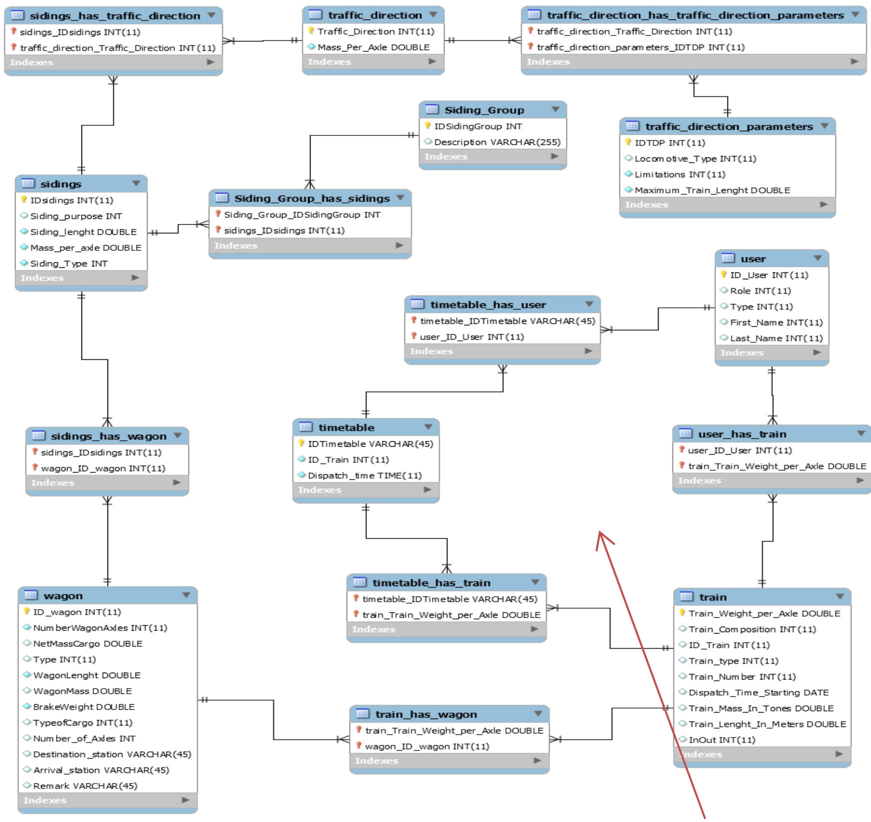


Diagram of database structure (logical schema) of Marshalling yard data

ID_wagon	NumberWagonAxles	NetMassCargo	Type	WagonLenght	WagonMass	BrakeWeight	TypeofCargo	Number_of_Axles	Destination_station	Arrival_station	Remark
1	33 56 4768303-6	39	S	15.0	26.2	000	CARINA	4	Preševo border	Vršac border	NULL
2	33 56 4768302-8	49.6	S	15.0	26.7	072	CARINA	4	Preševo border	Vršac border	NULL
3	33 56 4768307-7	51.9	S	15.0	26.7	072	CARINA	4	Preševo border	Vršac border	NULL
4	33 56 4768323-4	40.1	S	15.0	26.7	067	CARINA	4	Preševo border	Vršac border	NULL
5	33 56 4768316-8	40.3	S	15.0	26.6	072	CARINA	4	Preševo border	Vršac border	NULL
6	33 56 4768319-2	38.7	S	15.0	26.0	065	CARINA	4	Preševo border	Vršac border	NULL
7	33 56 4768309-3	40.0	S	15.0	26.0	066	CARINA	4	Preševo border	Vršac border	NULL
8	33 56 4768531-2	40.0	S	12.0	22.1	048	CARINA	4	Preševo border	Vršac border	NULL
9	33 56 4768540-3	40.3	S	12.0	22.1	000	CARINA	4	Preševo border	Vršac border	NULL
10	33 56 4768537-9	40.4	S	12.0	22.1	062	CARINA	4	Preševo border	Vršac border	NULL
11	33 56 4768528-8	40.6	S	12.0	22.1	063	CARINA	4	Preševo border	Vršac border	NULL
12	33 56 4768539-5	37.2	S	12.0	22.1	048	CARINA	4	Preševo border	Vršac border	NULL
13	33 56 4768313-5	15.6	S	15.0	27.4	043	CARINA	4	Preševo border	Vršac border	NULL
14	33 56 4768320-0	49.0	S	15.0	27.4	072	CARINA	4	Preševo border	Vršac border	NULL
15	33 56 4768520-5	14.6	S	12.0	21.1	048	CARINA	4	Preševo border	Vršac border	NULL
16	33 56 4768318-4	49.4	S	15.0	27.4	072	CARINA	4	Preševo border	Vršac border	NULL
17	31 79 2771122-4	[illegible]	H	23.2	26.4	041	CARINA	4	Preševo border	Šid border	NULL
18	31 79 2741085-0	13.8	H	23.2	26.1	041	CARINA	4	Preševo border	Šid border	NULL
19	31 79 2891026-2	16.4	H	23.2	27.4	044	CARINA	4	Preševo border	Šid border	NULL

Real wagon data from SMART database

IDsidings	Siding_purpose	Siding_lenght	Mass_per_axle	Siding_Type
[illegible]	multipurpose	693	D3	both-sided
1a	multipurpose	152	D3	both-sided
1b	multipurpose	121	D3	both-sided
2	receiving	681	D3	both-sided
3	receiving	640	D3	both-sided
4	receiving	638	D3	both-sided
5	receiving	675	D3	both-sided
6	receiving	719	D3	both-sided
7	receiving	765	D3	both-sided
8	receiving	768	D3	both-sided
9	receiving	884	D3	both-sided
10	classification-departure	838	D3	one-sided
11	classification-departure	759	D3	one-sided
12	classification-departure	708	D3	one-sided
13	classification-departure	751	D3	one-sided
14	classification-departure	803	D3	one-sided
15	classification-departure	702	D3	one-sided
16	classification-departure	702	D3	one-sided
17	classification-departure	733	D3	one-sided
[illegible]	[illegible]	[illegible]	D3	[illegible]
19	classification-departure	594	D3	one-sided
20	classification-departure	636	D3	one-sided

Data for sidings in SMART database

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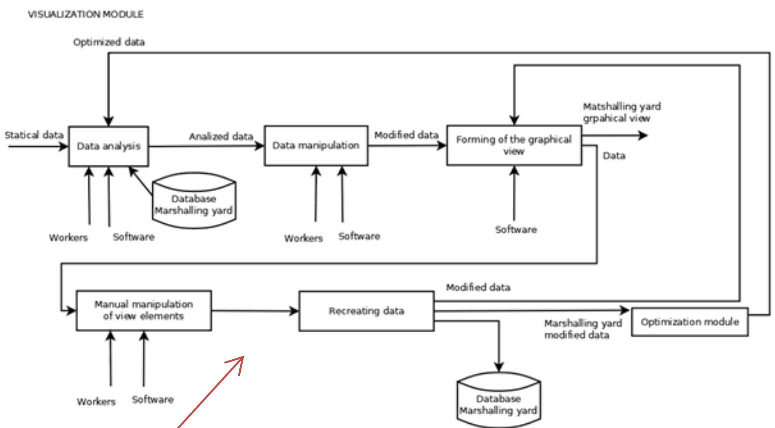
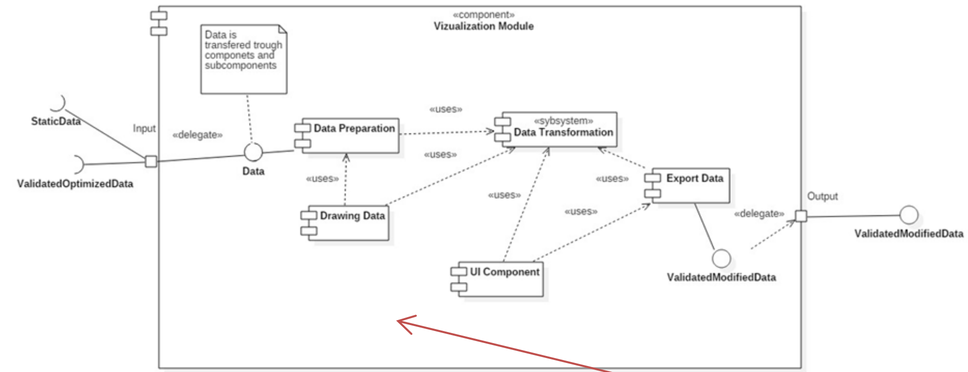
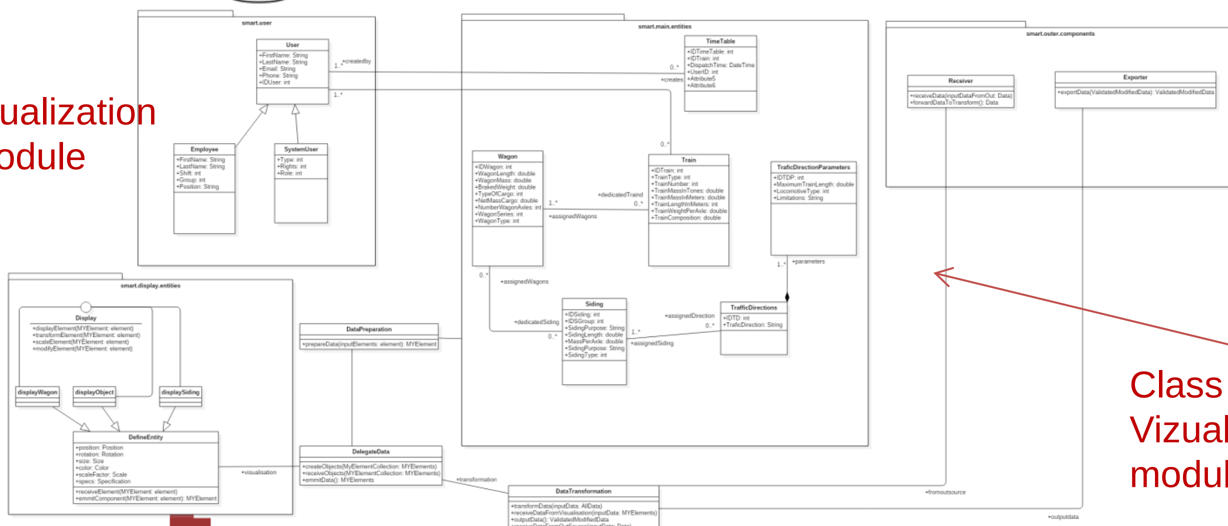
SMART Real-time Marshalling Yard Management System

- Visualization and planning module







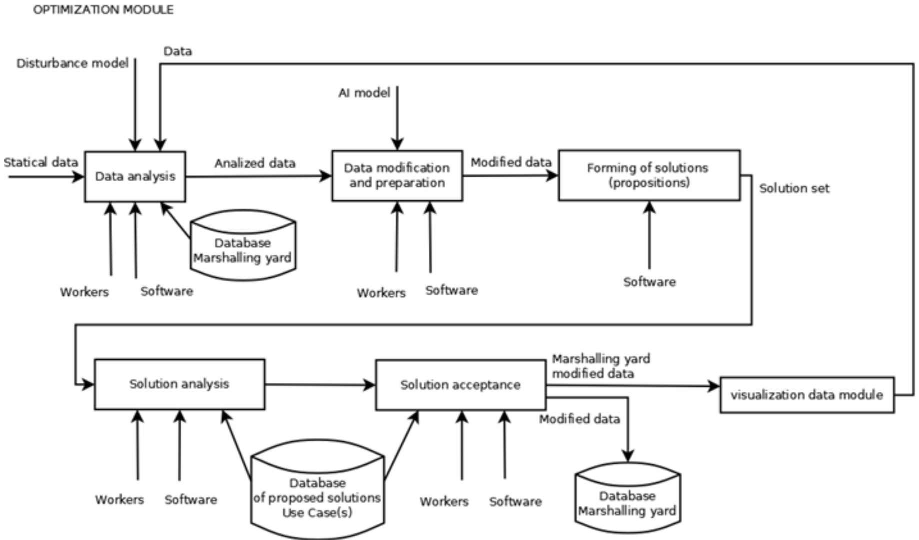
Data flow of Vizualization and planning module

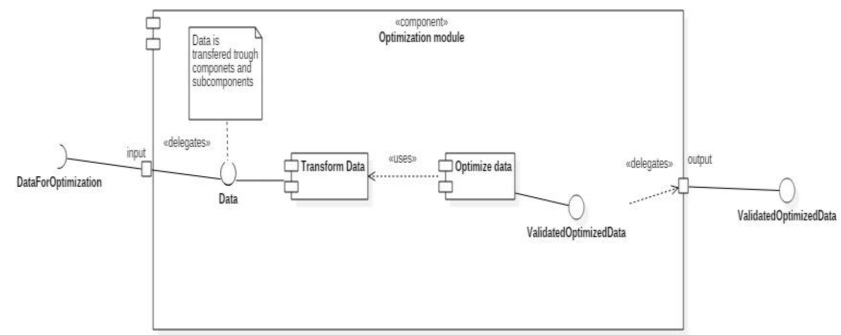
Component diagram of Vizualization and planning module

Class diagram of Vizualization and planning module

SMART Real-time Marshalling Yard Management System

- Optimization module





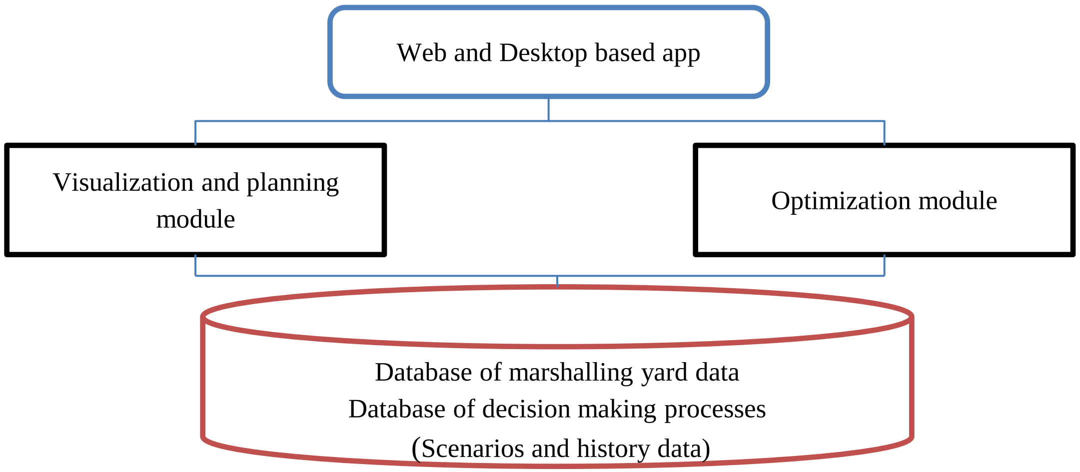
Component diagram of Optimization module

Process and ata flow of Vizualization and planning module

3 optimization criterias are selected:

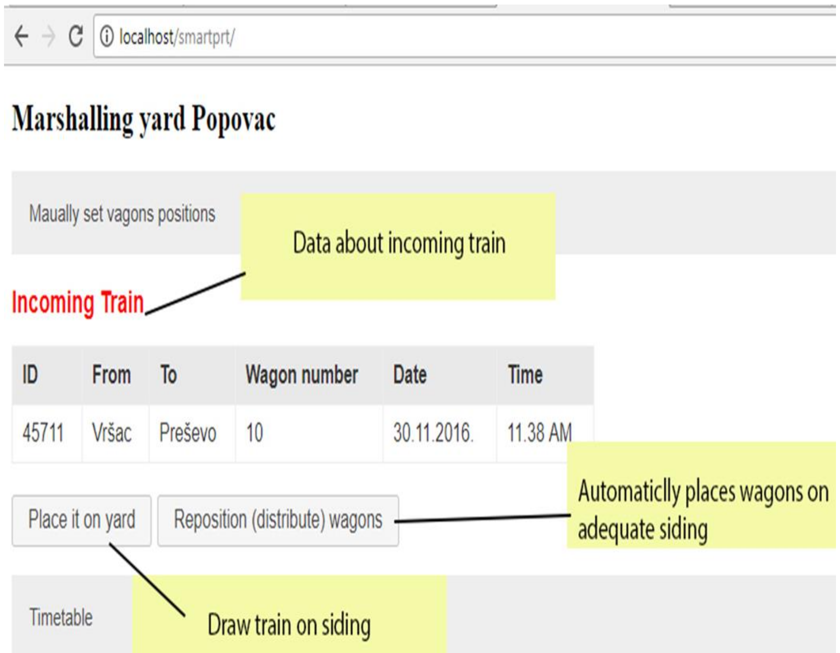
- Time
- Energy consumption
- Cost

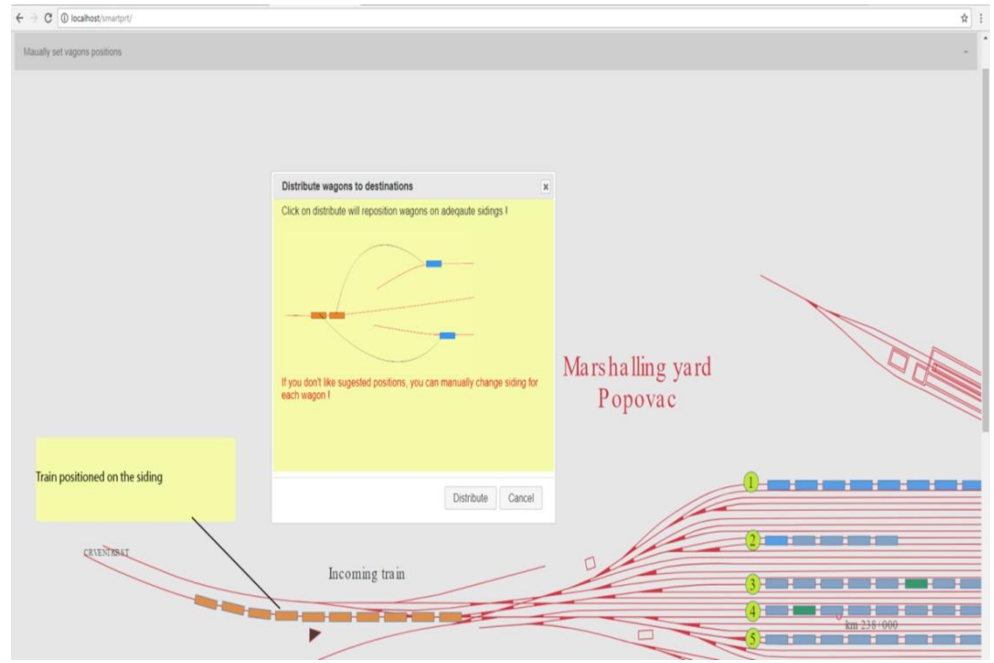
SMART Real-time Marshalling Yard Management System



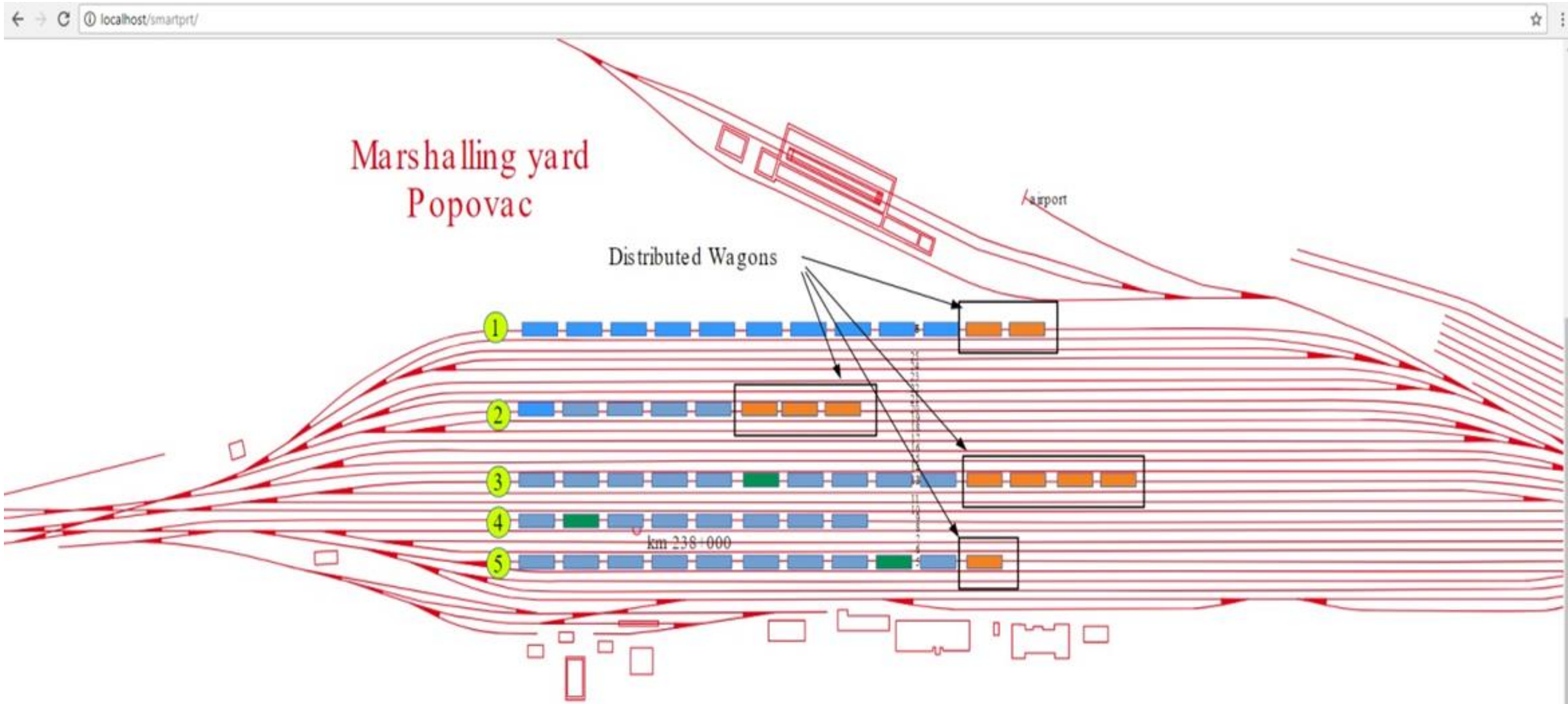
- Application is created in such manner that it can work as online web application and in offline mode, as standard desktop application.
- Both modules have Front End part oriented to the user, and Back End part which contains business logic of the application.
- Marshalling yard data is inserted and 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



Incoming Train

ID	From	To	Wagon number	Date	Time
45711	Vršac	Preševo	10	30.11.2016.	11.38 AM

Place it on yard | Reposition (distribute) wagons

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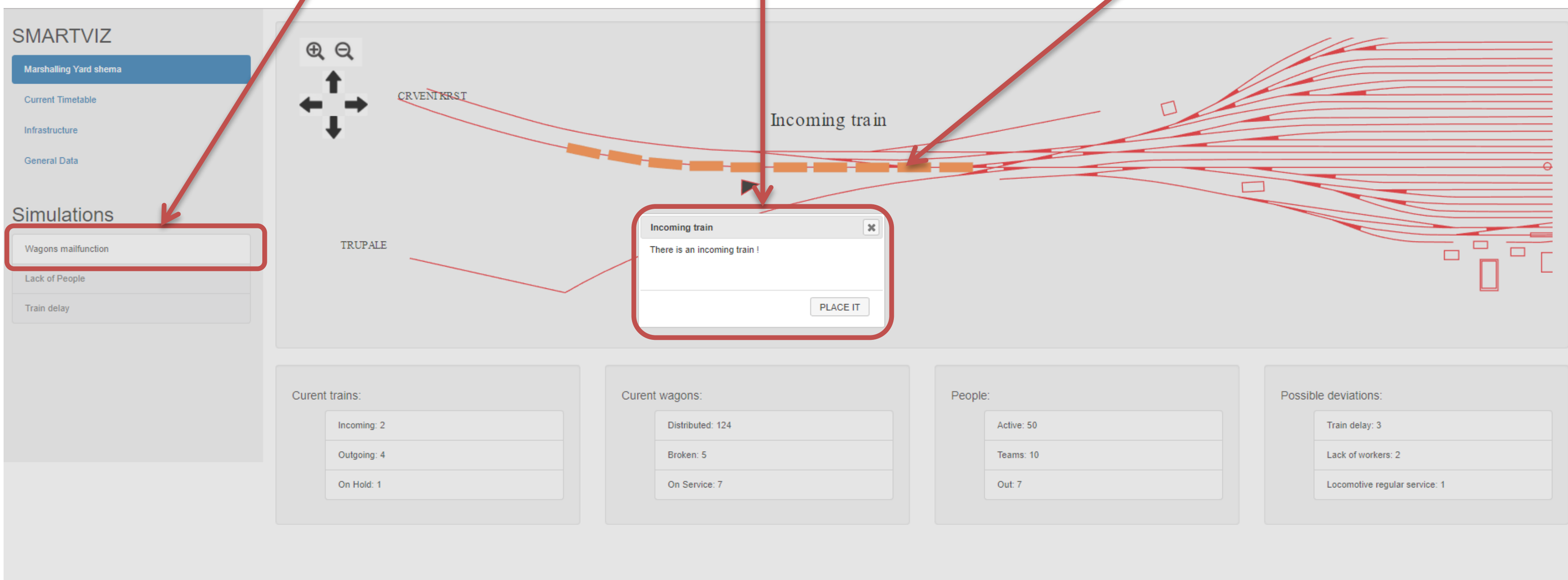
Simulation of incoming train - Wagon mailfunction

Types of simulation

Alert window

Incoming train



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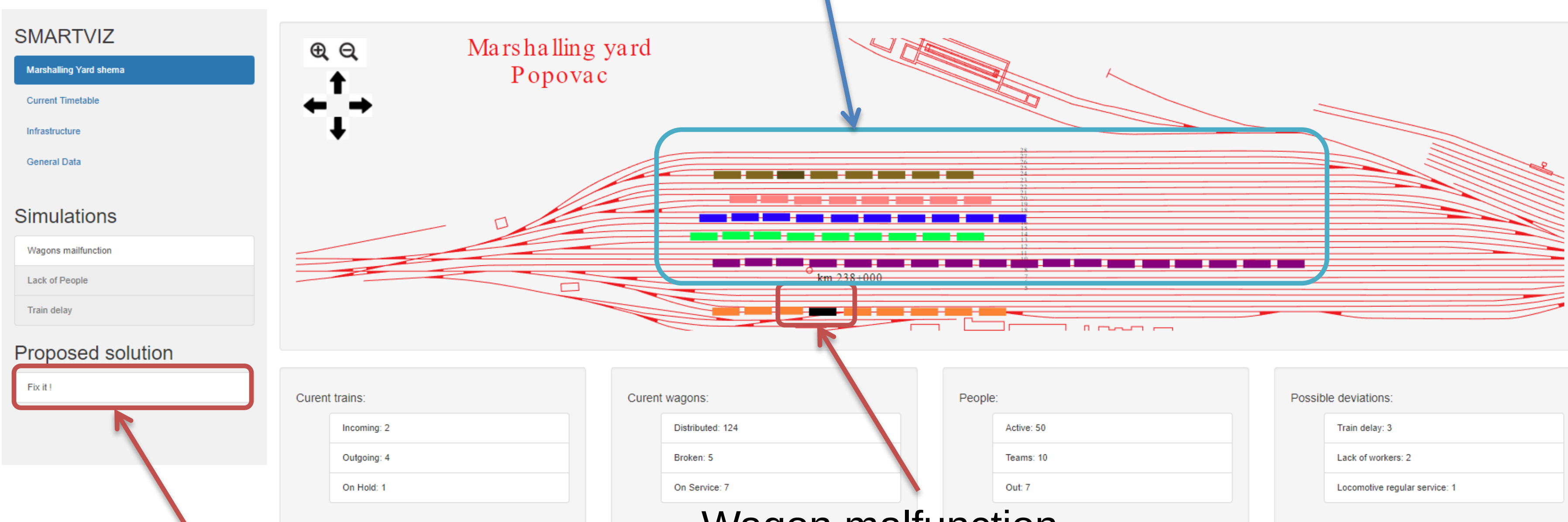
Simulation of incoming train - Wagon mailfunction

Positioned trains



Wagon malfunction

Solution

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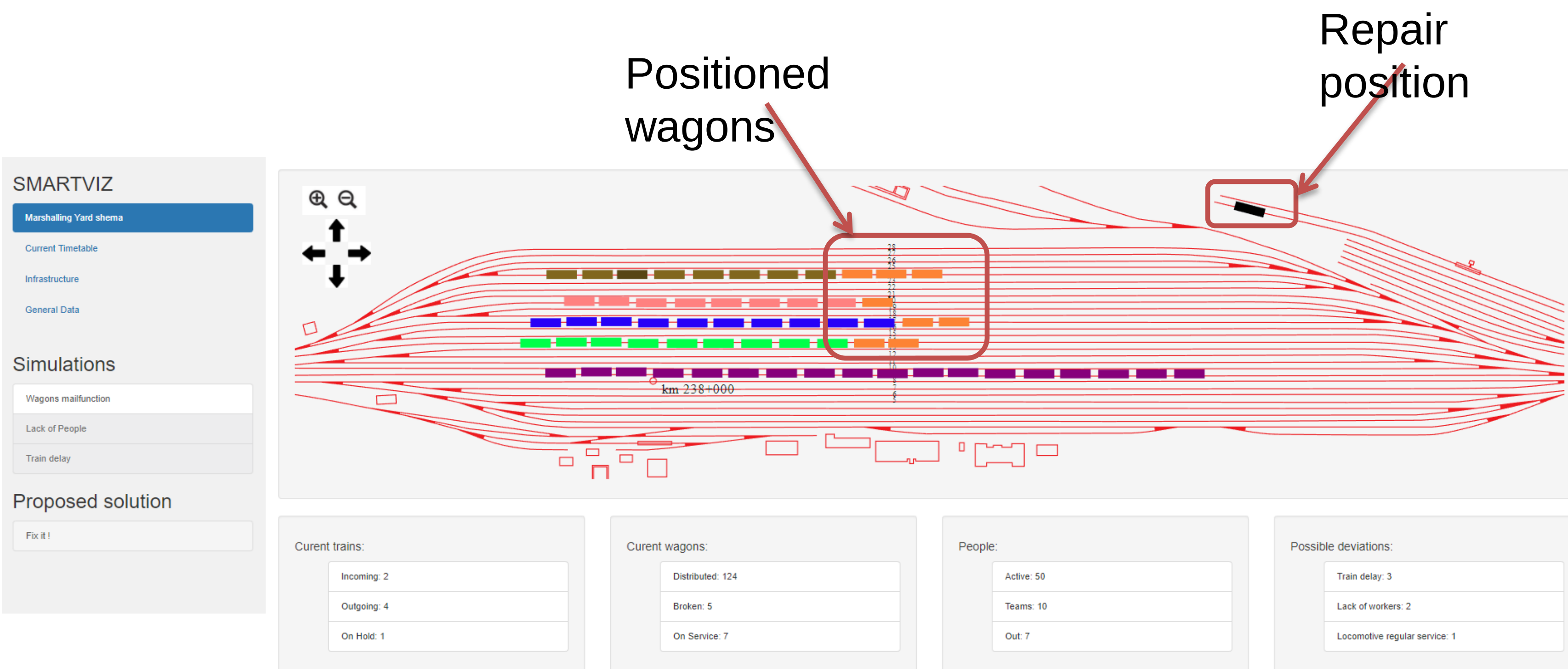
Simulation of incoming train – Proposed solution



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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!

www. smartrail-automation-project.net

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