Ana M. Moreno

Los Tranvías de Zaragoza

Zaragoza

700,000 inhabitants
The 4th most populous city in Spain

Geoestrategic hub
Equidistant (300 km) from Madrid, Barcelona, Bilbao and Valencia

Line 1

Length: 12,8 km
Number of stops: 25
Number of trams: 21
Length of trams: 32 m to 42 m
Capacity: 200 passengers
Supply: Catenary, except in the city center: Gran Vía – Chimenea (2 km)
Frequency (peak hour): 5’
Total trip North-South: 40’
Distance between stops: 500 m
Interchangers: 3
Intermodal parking lots: 2
Depots and workshops: 2
Beggining 1st Phase: August 2009
Beggining 2nd Phase: February 2011
Complete line: March 2013

More than 100,000 passengers / day

The tramway line with the highest demand in Spain

2019 demand: 28,873,814 passengers

Close to the 30% of the city's public transport, with only one line

15% less traffic in average in the whole city, up to 30% in the city centre

How do we see the future?

AI: Trams of the future

According to ChatGPT:

How the urban public transport will be in the future:

- Public-private partnerships
- Green spaces and pedestrianization
- Environmental considerations
- Electrification and sustainable solutions
- Inclusive design and accessibility
- Smart technology
- Multimodal transportation networks
- Data-driven decision making
- Autonomous vehicles

Public – private partnerships

Tranvía de Zaragoza business structure

tranvía
zaragoza

=

80% TRAZA (CAF + tuzsa + TIIC + acciona + FCC)

+

20% Z

Green spaces and pedestrianization

An opportunity to upgrade the city

Upgraded boulevards, sidewalks and bridges along 12.8 km

More than 42,000 m2 of natural grass with drip irrigation

Environmental considerations

Research of CIRCE Institute (University of Zaragoza)

With the tram, Zaragoza saves 19.6 million litres of fuel per year

Since the tram started up, the city avoids per year:

- 481 Tn of NOx
- 293 Tn of CO2
- 17 Tn of solid particles (PM10)

Sustainable solutions

All the energy used in the Zaragoza Tram comes from renewable sources

Inclusive design and accesibility

Working together for disabled people along with organizations such as ONCE and DFA Foundation

Smart technology

Dynamic Priority System and crowd levels

Full Dynamic Priority System:
- 172 junctions along the line and 13 traffic light junctions per km
- Commercial average speed of 19.5 km / h
- 200 security cameras and 1 central computer

Crowd level information for passengers in real time

Multimodal transportation networks

Integrated tickets and cards and transfers included

Joining the MAAS Project of Zaragoza City Council

Data-driven decision making

The first CAF's 100% digital depot in the World

GPS antenna

Cloud services by Amazon AWS

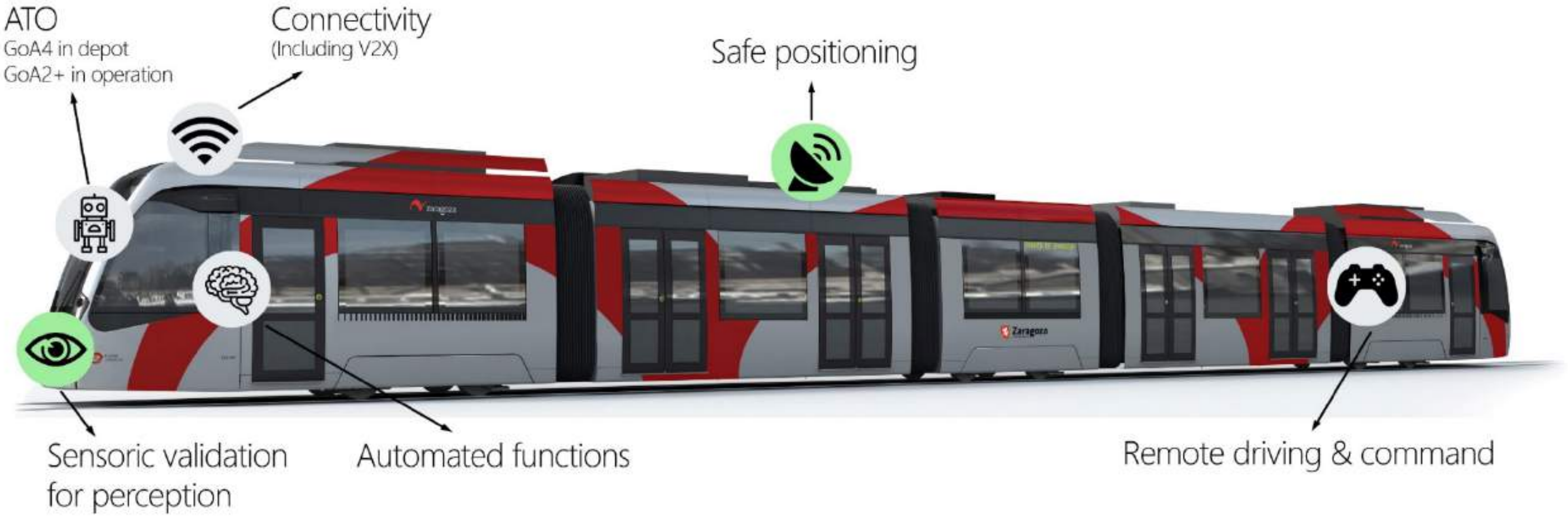
- Data reception, transformation and storage
- Data processing and analyisis
- Display to users

LeadMind®

EASING THE WAY TO FUTURE MOBILITY

Autonomous vehicles

TAURO Project: autonomous tram



TAURO

Europe's Rail

CAF

tranvía
zaragoza

Two main lines

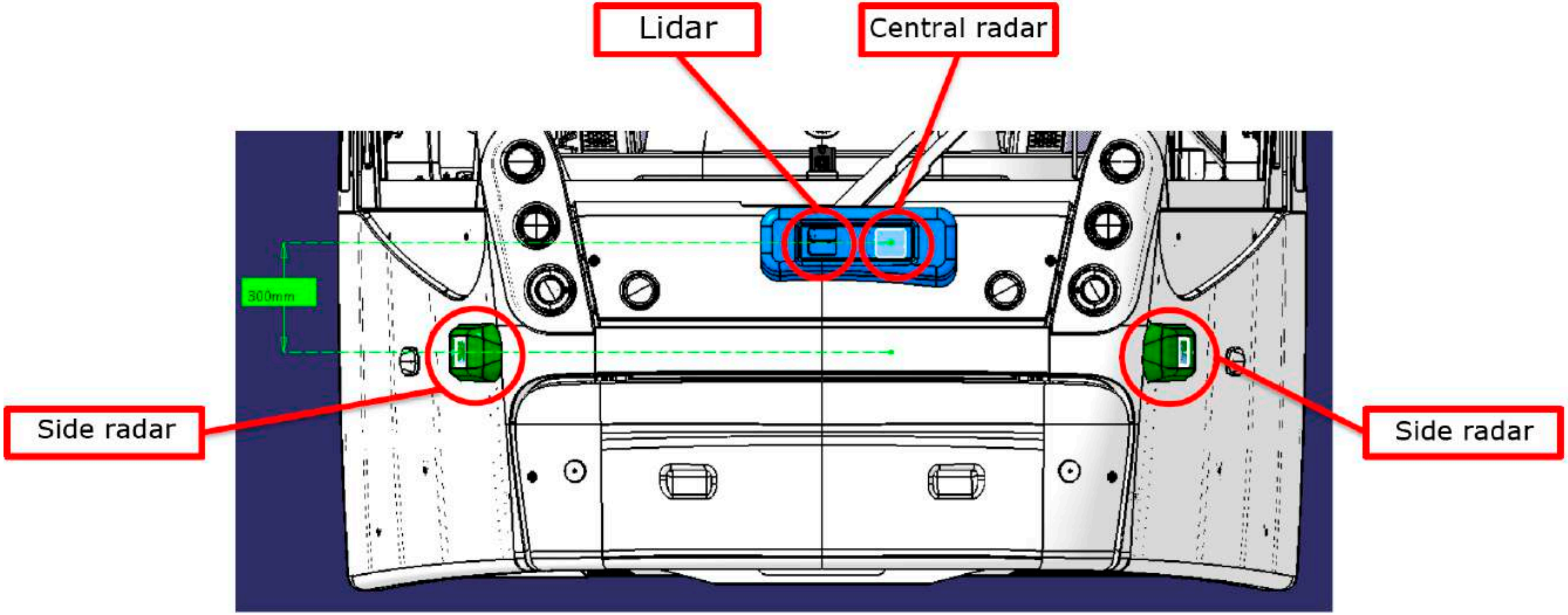
Safe positioning

- ✓ Generation of the digital map
- ✓ Feasability analysis of the use of Radar and Lidar for localization
- ✓ Integration with data from other sensors to achieve a secure positioning (GNSS, Odometry, etc)
- ✓ Search for an integrated proposal with all the available information

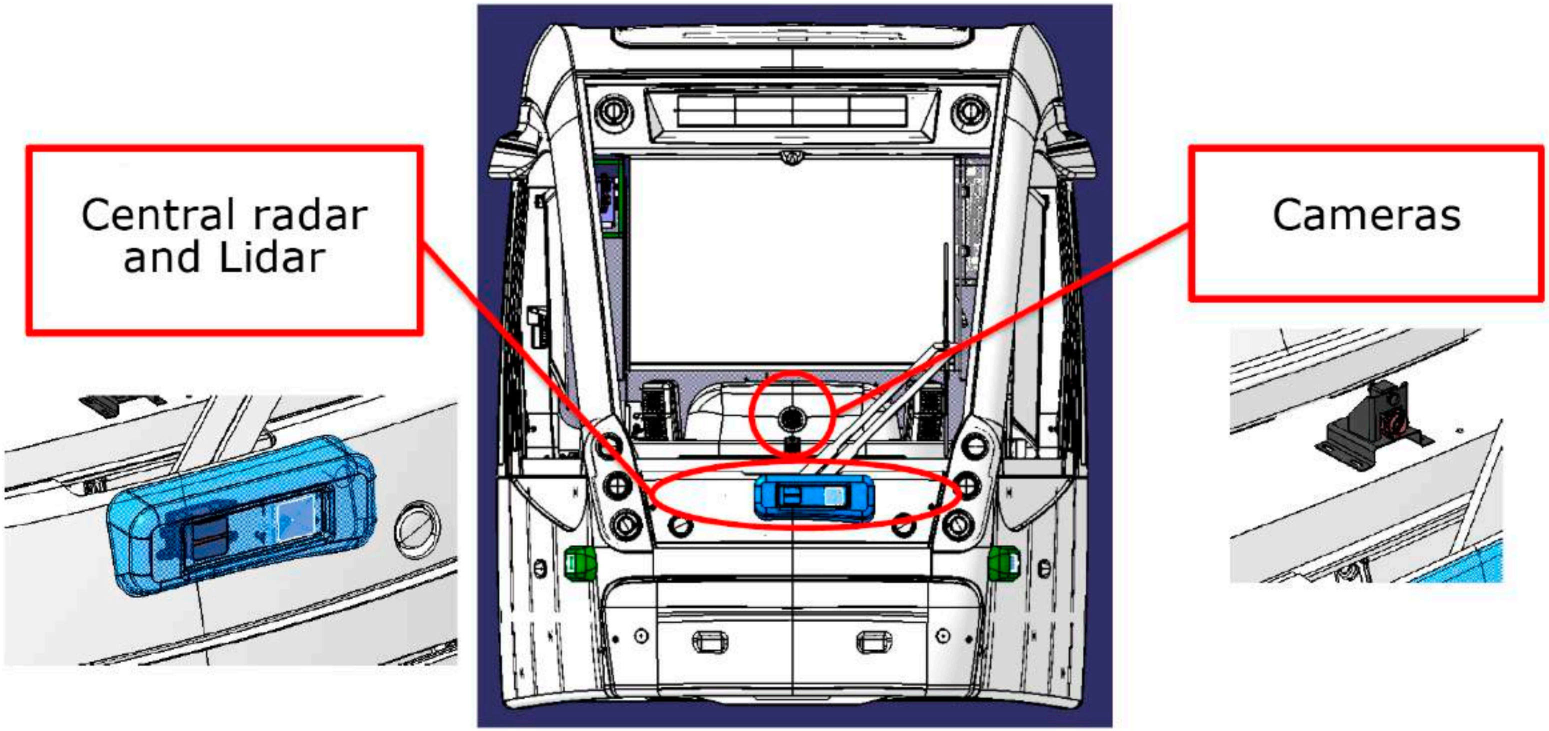
Sensoric validation for perception

- ✓ Analysis of prediction results using different combinations of perception sensors (cameras, Radar, Lidar, etc)
- ✓ Compatibility and identification of restrictive use cases with each sensor.
- ✓ Study of the impact of environmental conditions of the outcome

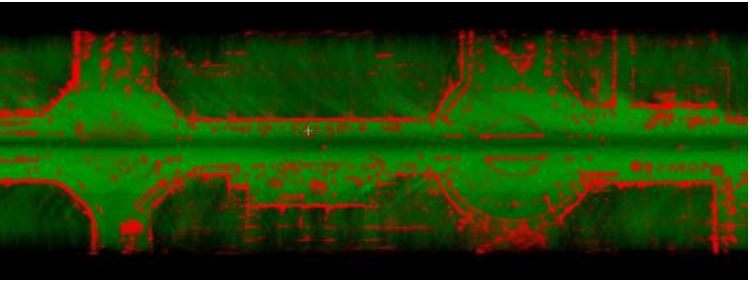
Three radars in each cabin



Solid-state Lidar and two cameras



Positioning



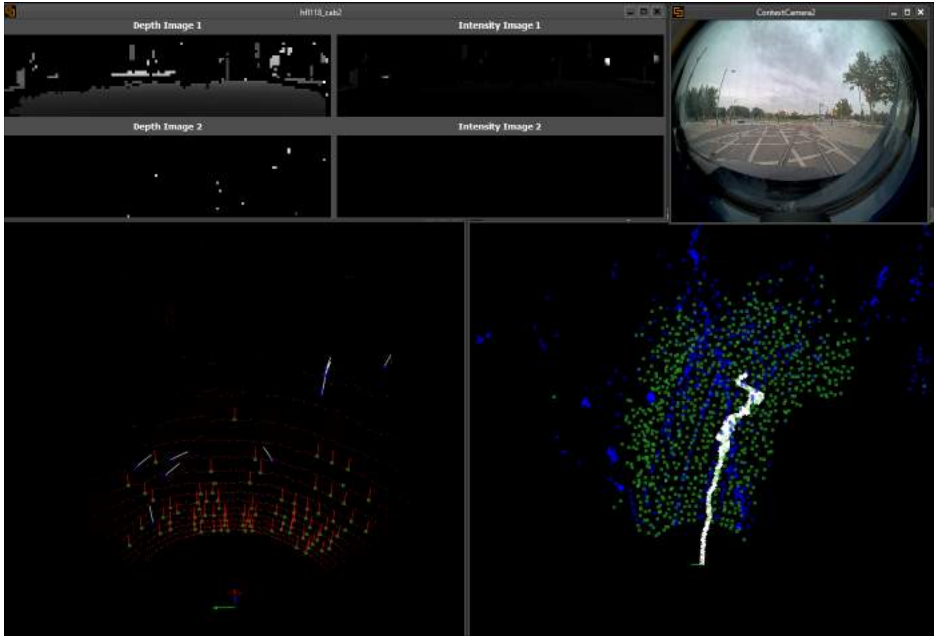
EU Rail TAURO has already finished. The research performed clarifies the following questions:

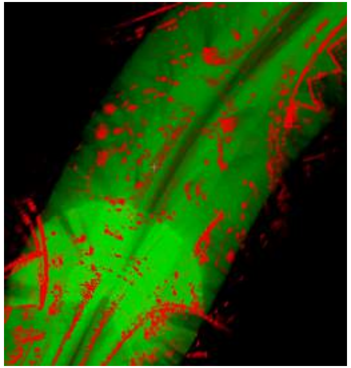
- Limitations of sensors.
- Impact on the position of the sensors.
- Comparisons between the SLAM (Simultaneous Localisation and Mapping) algorithm and Ground Thruth
- Accuracy and quality of results
- Optical and electrical crosstalk

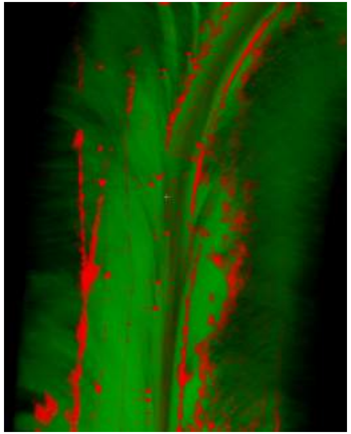
All details are publicly available (report D1.3 in the project website www.s2r-tauro.eu)

Positioning

Lidar and Radars tracks in different infrastructure sections





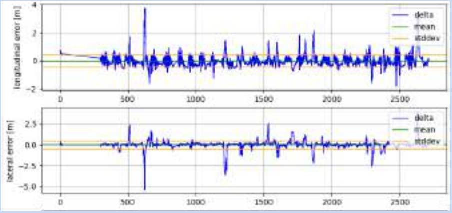


Positioning conclusions

The use of the Lidar makes possible to achieve relative positioning functions with no need of a static map. The margins of positioning errors obtained show accuracies in a range of 5 metres, provided that an absolute reset is perfomed every 100 metres. For other cases, see chart:

Distancia de reseteo del offset	Valor del radio de error
100 m	≈ 5 m
200 m	≈ 14 m
300 m	≈ 29 m

Digital map-based radar track analysis show positive data as long as GNSS signal is available. Preliminary results show errors of less than one metre:



	Media	Std dev.	Max.
Absolute position error (m)	0,360	0,525	6,09
Longitudinal error (m)	0,266	0,429	3,73
Lateral error (m)	0,243	0,524	5,38

Perception

In Zaragoza, there have been considered six study situations under different climatic conditions:

- Sunrise
- Sunset
- Midday
- Night
- Foggy condition
- Rain
- Combination of the above

Data have been merged in four different stages:

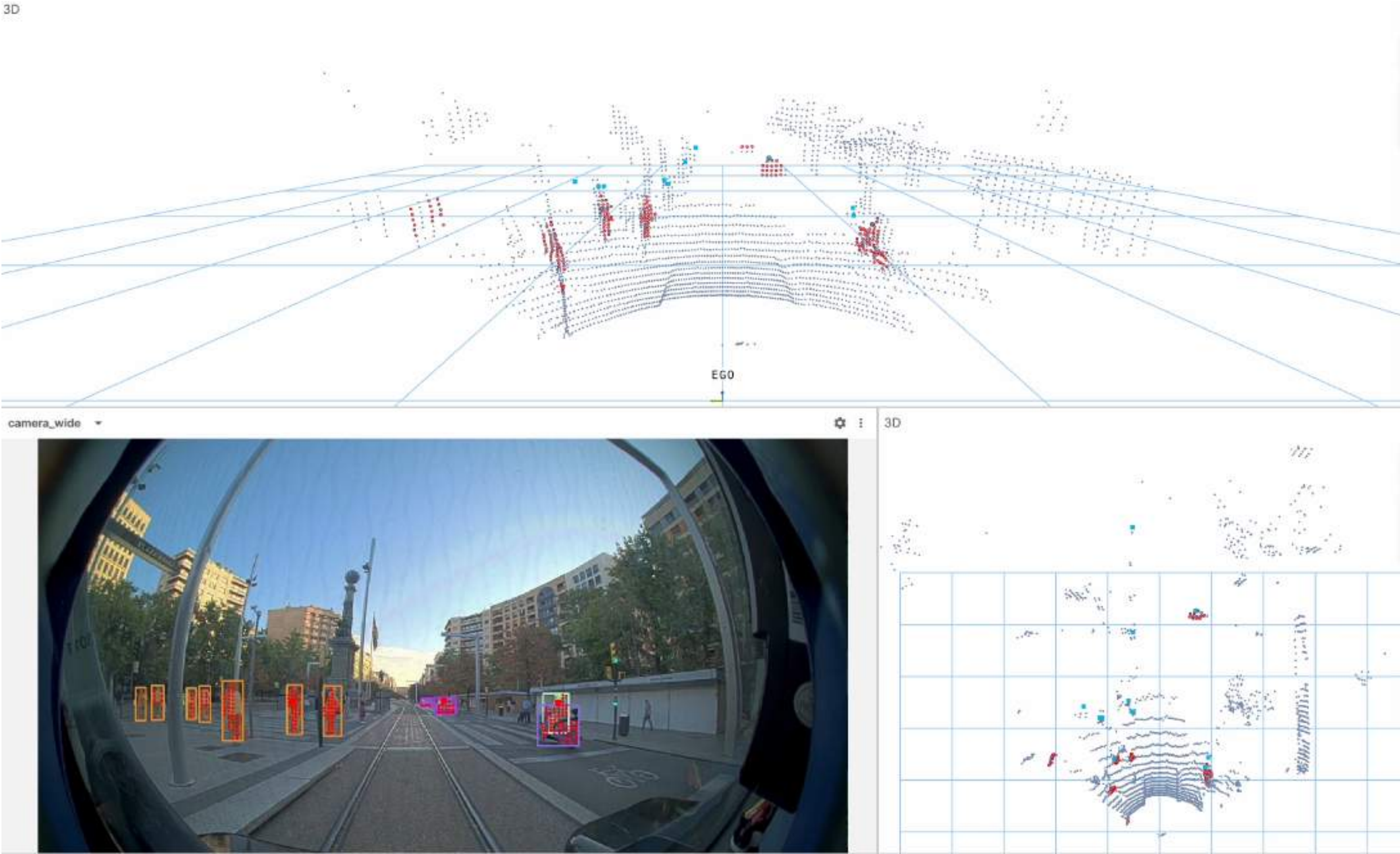
- RGB camera (no merging)
- Camera + Radar
- Camera + Lidar
- Camera + Radar + Lidar

Perception

Camera-based object detection and identification:

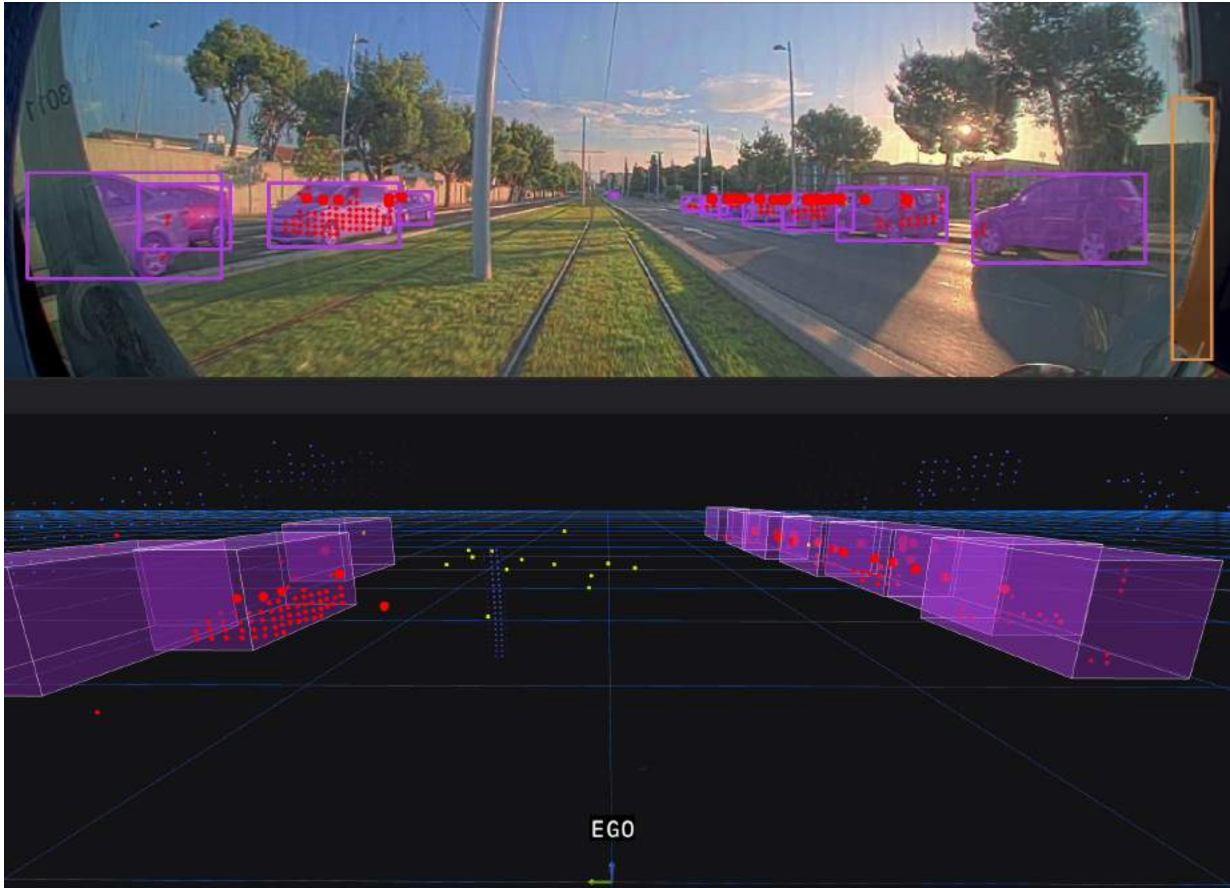
Perception

Camera + Lidar:



Perception

Camera + Radar + Lidar:



Perception conclusions

The amount of images obtained in different environments, visibility conditions and situations have enabled to:

- Identify static and moving objects, and their characterization and tracking
- Evaluate the potential of each sensor and the data merging to achieve optimal perception results
- Obtain reliable, objective, and comparable metrics in order to evaluate algorithms
- Generate a data file which enables to train and validate perception algorithms in the particular features of Zaragoza

Next steps: ADAS in Zaragoza

Obstacle detection system:

- Sensorization set-up in trams in order to detect objects that could potentaly collide with the tram
- Evaluate the risk level and warn the driver if a collision could happen
- Enhance driver's perception and passenger's safety

Next steps: functionalities in depots

- Analysis of the functionalities that could be made remotely or autonomously in order to enhance safety and efficiency
- Development and implementation of remote driving and telecommanding systems
- Implementation of autonomous movements inside the depot

Last step: autonomous tram

Objective: Enhance:
- Safety
- Efficiency
- Availability

Main challenges:
- To develop the legal framework for this new reality
- To manage ethical issues
- To define the type of policy together with insurance companies
- To stablish the employees new roles
- To reach citizens confidence
- To improve cybersecurity

Back to ChatGPT:

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- Environmental considerations ✓
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- Inclusive design and accessibility ✓
- Smart technology ✓
- Multimodal transportation networks ✓
- Data-driven decision making ✓
- Autonomous vehicles ✓

Thank you

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