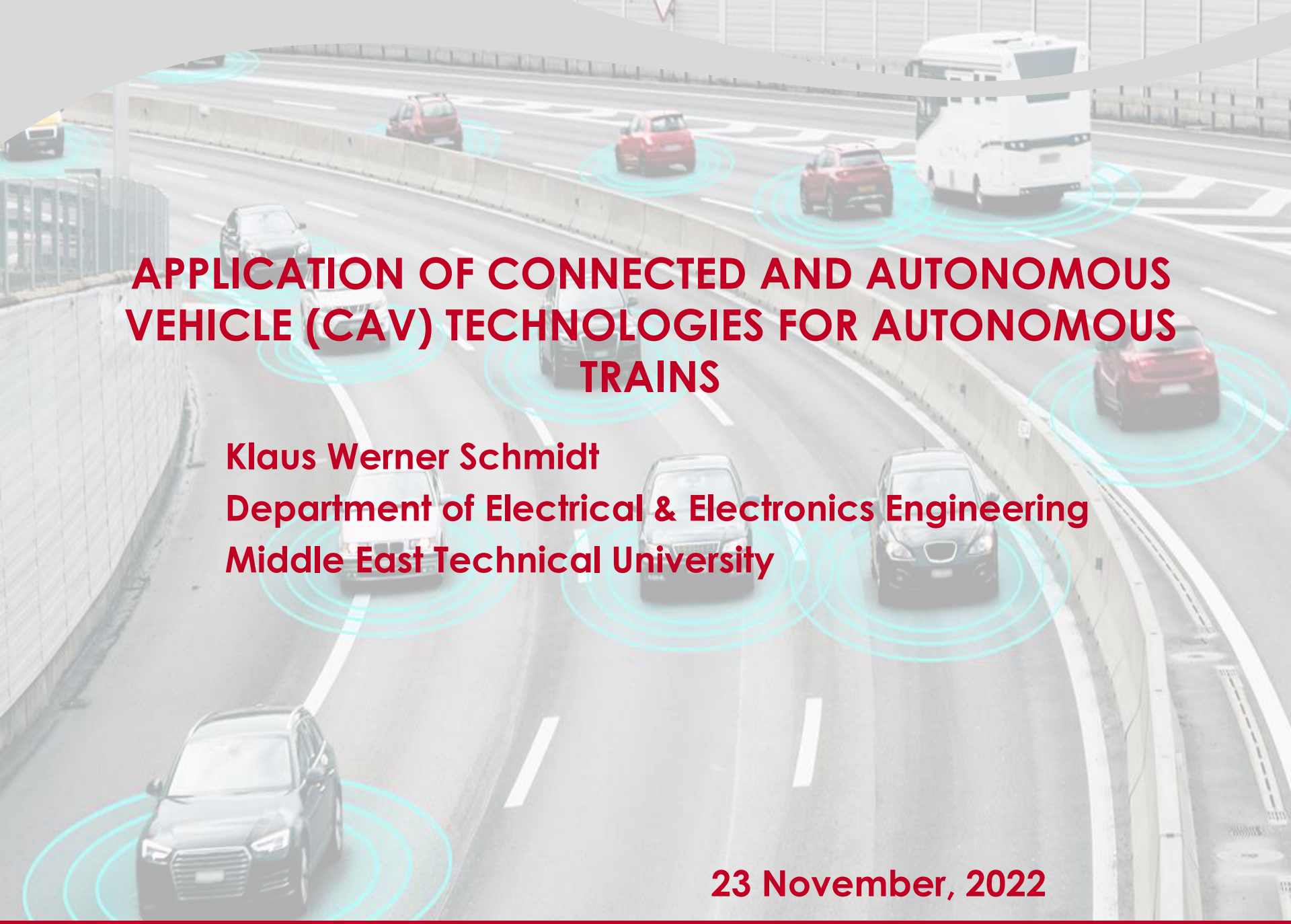

APPLICATION OF CONNECTED AND AUTONOMOUS VEHICLE (CAV) TECHNOLOGIES FOR AUTONOMOUS TRAINS

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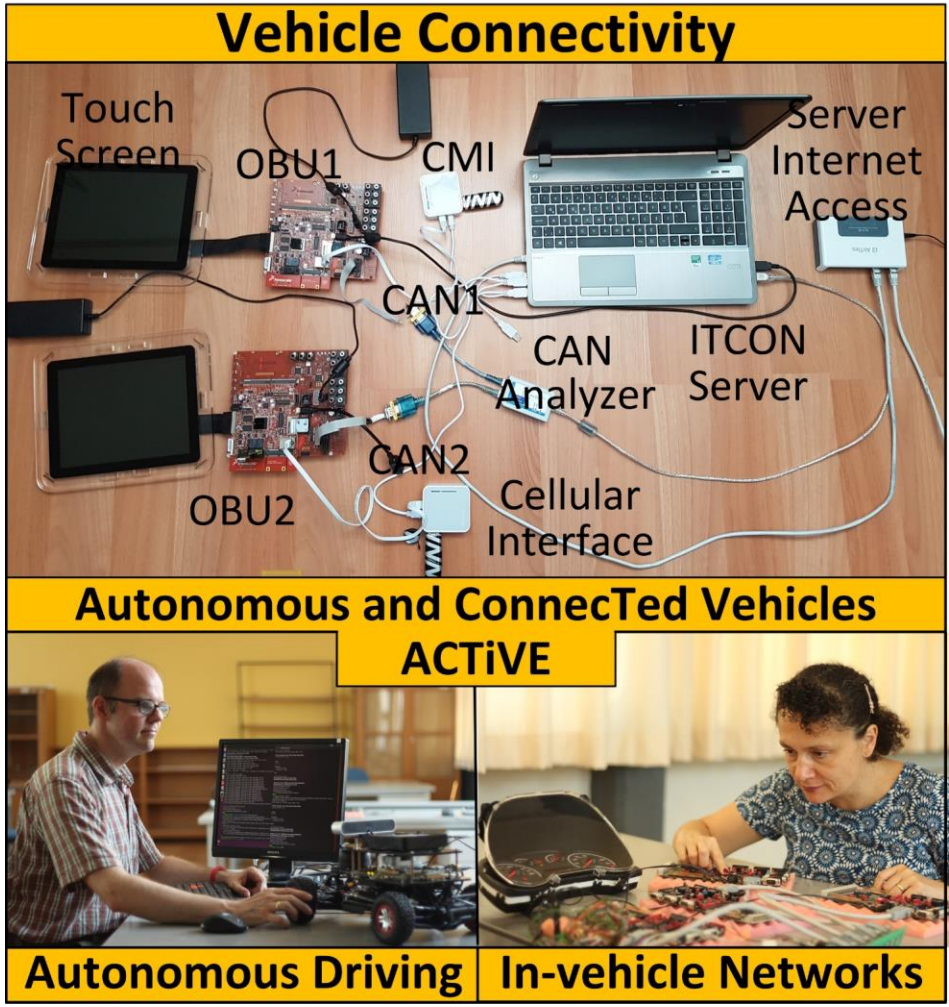
23 November, 2022

Active Lab

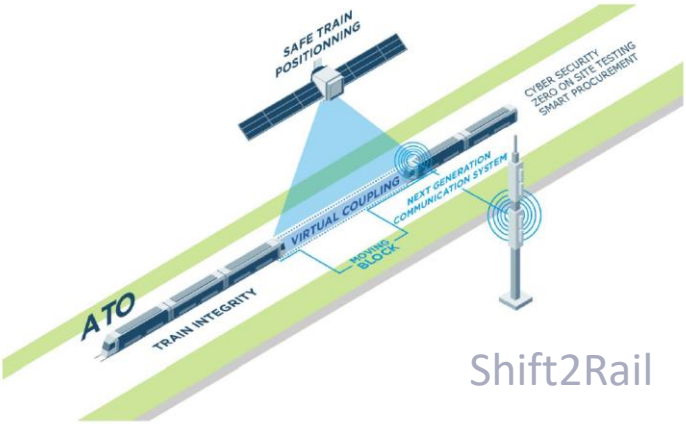
- Topics
  - Autonomous driving applications
  - Sensor data processing
  - Model-based control
  - Simulation
  - Real-time embedded systems
  - In-vehicle communication
  - Vehicle-to-everything (V2X) communication
  - Train communication network (TCN)



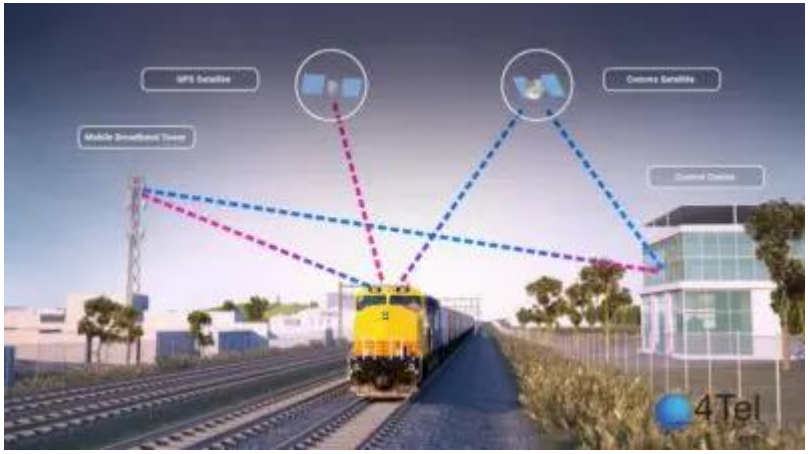
Motivation

- Autonomous Trains
  - Improve the overall safety
  - Increase existing capacity
  - Lower operational costs
  - Improve service reliability
  - Improve energy efficiency

⇒ **Very similar to CAVs**



Shift2Rail



Nvidia Blog

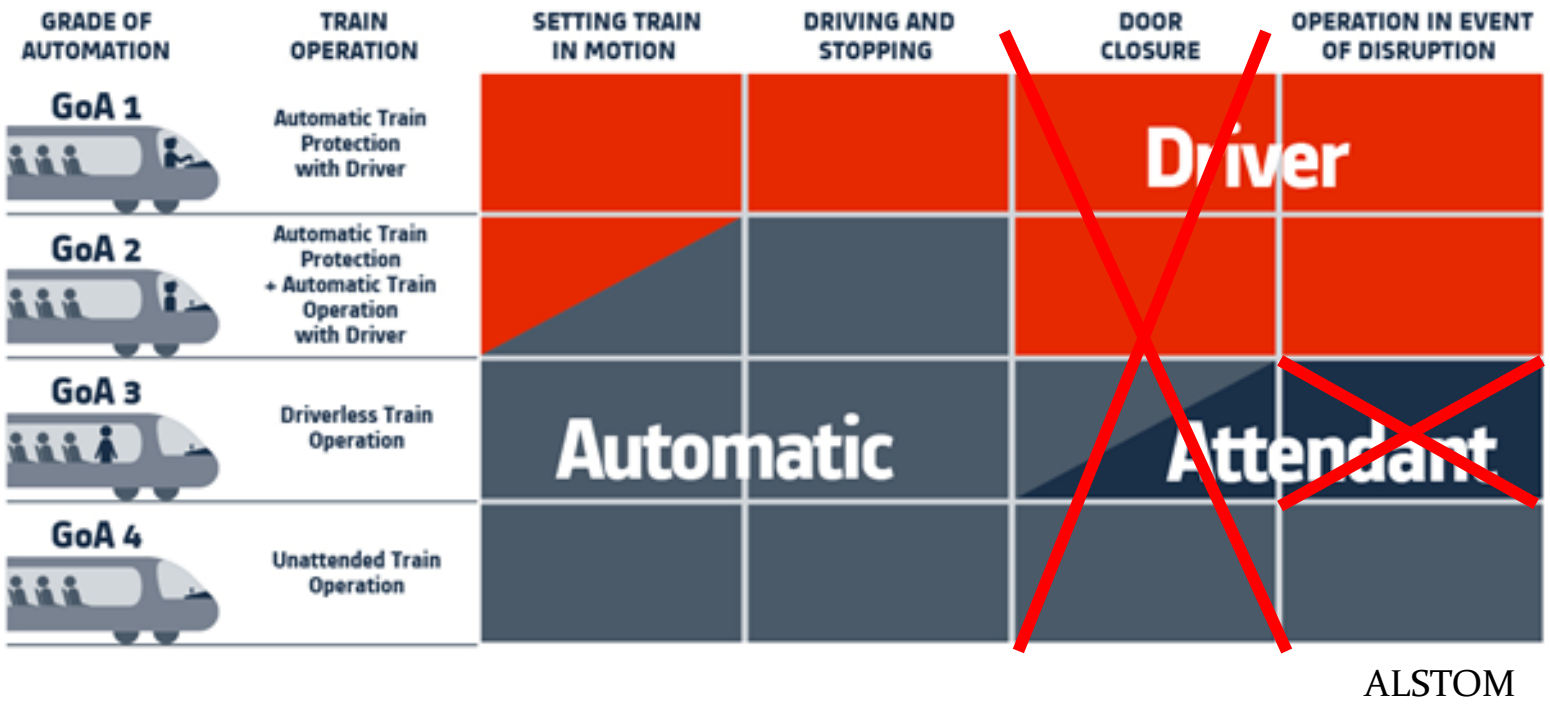
Taxirail SAS

Outline

- Motivation
- Autonomy Levels
- Architectural Considerations
- Sensor Technologies
- Example Correspondences
- Summary

Classification of ATs: GoA Levels

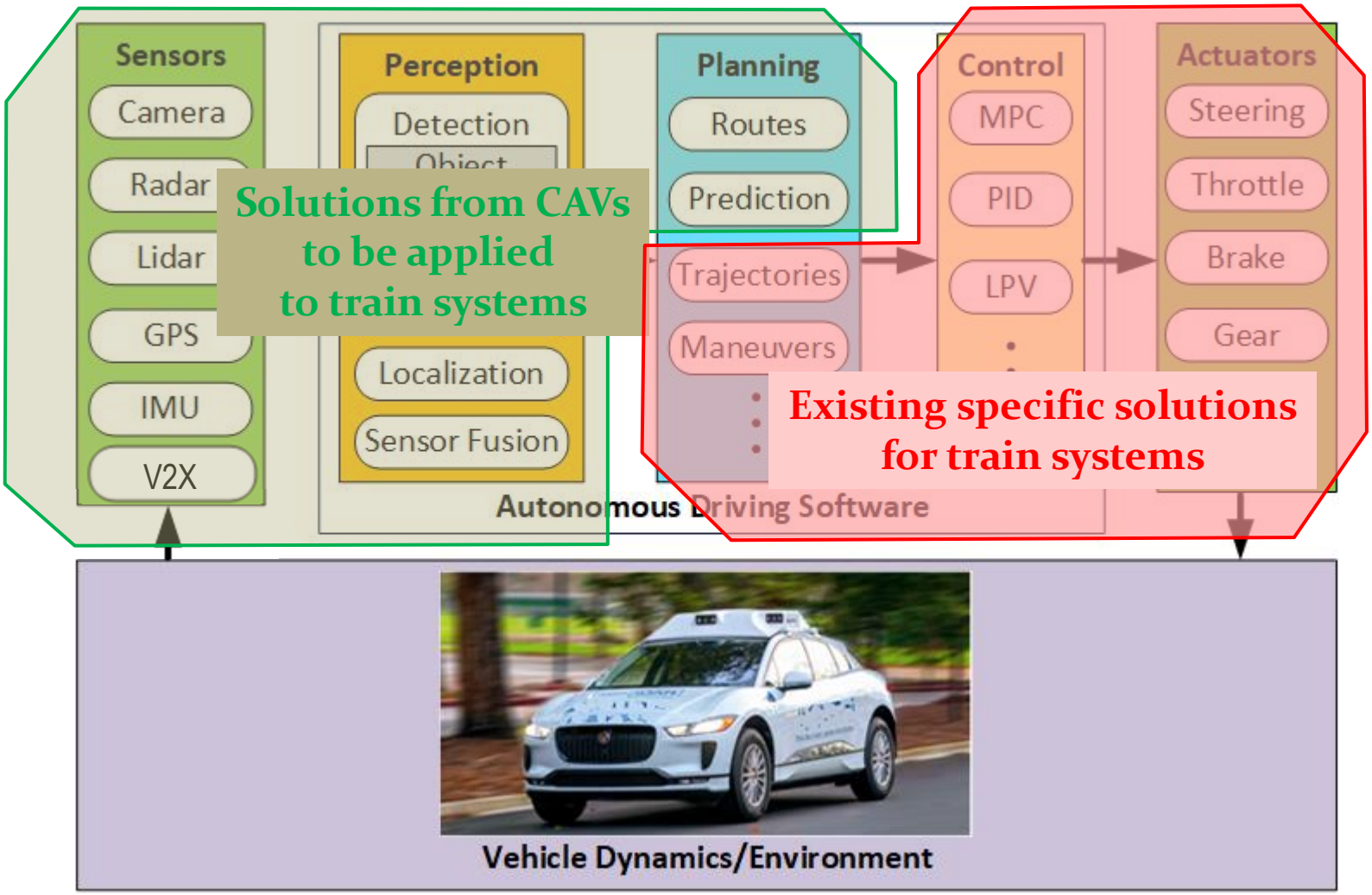
- Automatic Train Operation: Grade of Automation



ALSTOM

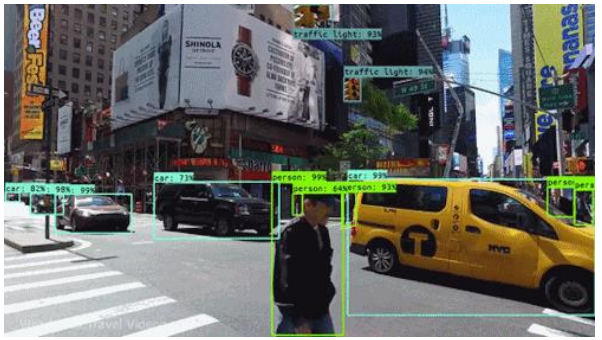
⇒ **CAV Technologies are applicable to several subproblems**

CAV System Architecture: Relevant Components

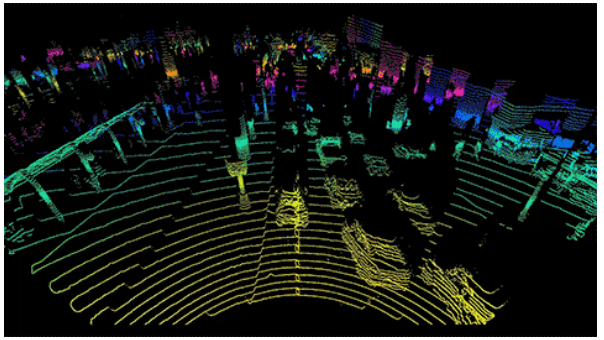


AV Components: Sensors

- Cameras
  - Provide 360° field of view
  - Object detection
  - Lane detection
- Lidar (Light Detection and Ranging)
  - Shape/depth of environment
  - Object detection/localization
- GPS/IMU
- V2X Communication



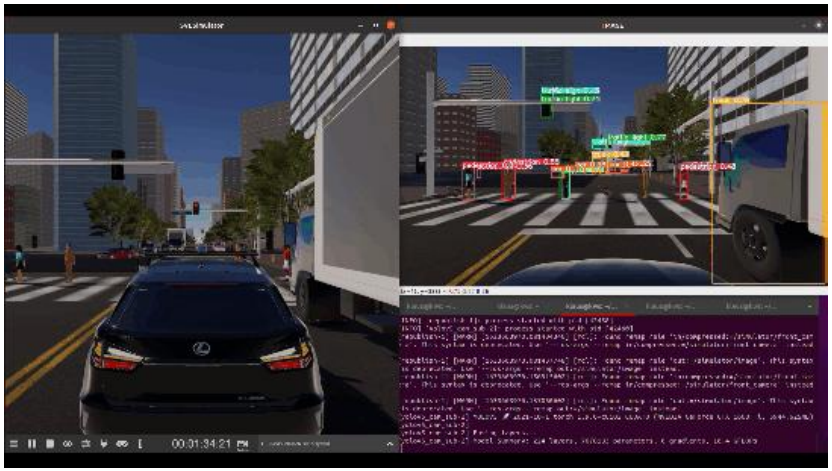
Analytics Vidhya



The New York Times

Examples: Vision-based Object Detection

- Common Methods
  - Deep neural networks
- Similarities
  - Objects (cars, trains, people)
  - Real-time requirements
- Differences
  - Relevant distances
  - Environment
  - Scenarios
- Conclusions
  - Similar methods
  - Different training/test data



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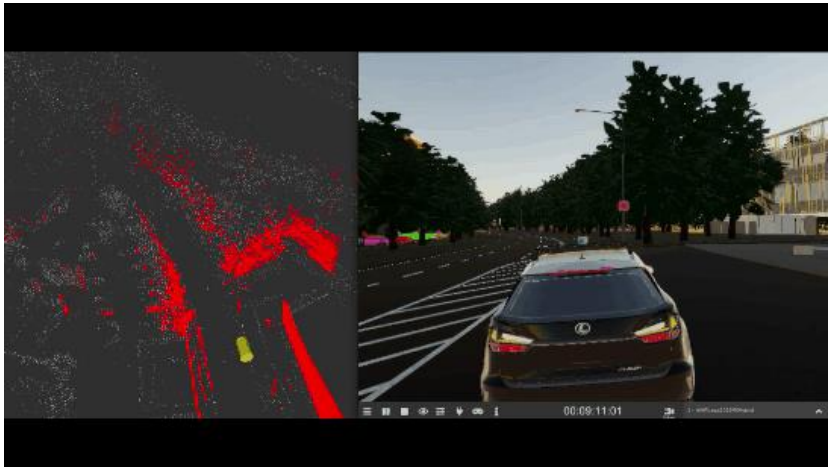
Transportmen

Examples: Lidar Localization

- Common Methods
  - Point cloud mapping
  - 3D registration algorithms
- Similarities
  - Sensor technology
  - Real-time requirements
- Differences
  - Environments
  - Vehicle motion
- Conclusion
  - Similar methods
  - Different features



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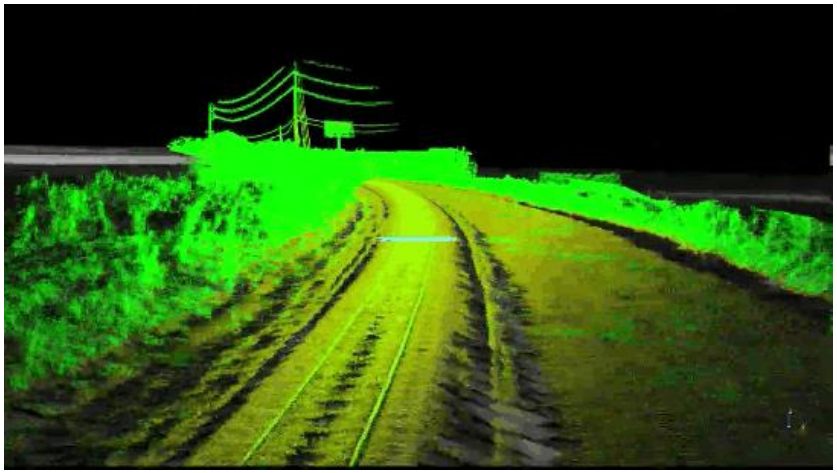


Realitxy IMT Inc.

Examples: Vision- and GPS-based Localization

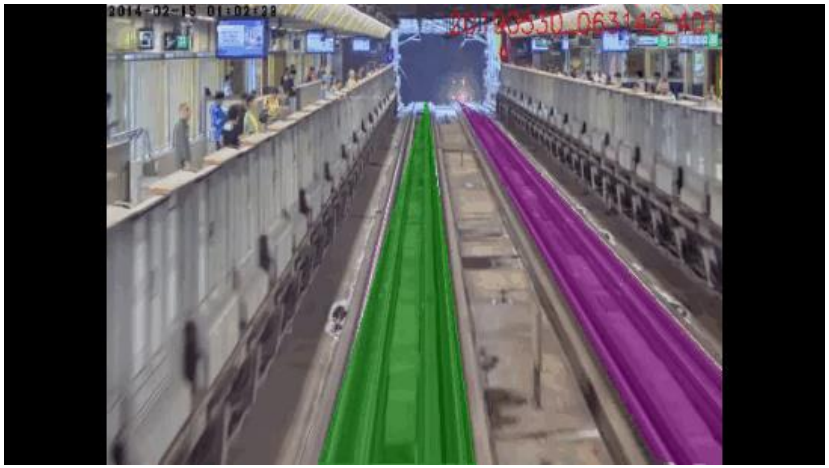
- Vision-based Localization
  - Lane detection for CAVs
  - Track detection for ATs

  ⇒ Application of same methods

Hackster.io

- GPS-based Localization
  - CAVs: Sensor fusion with motion data
  - ATs: Sensor fusion with inertial navigation data

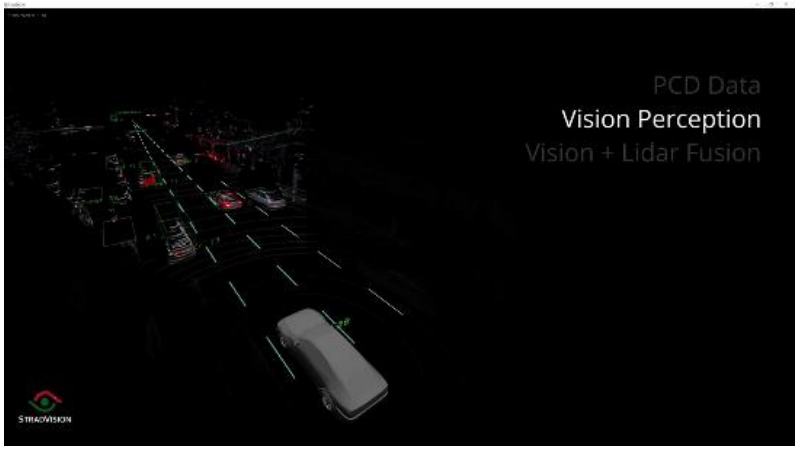
  ⇒ Application of same methods



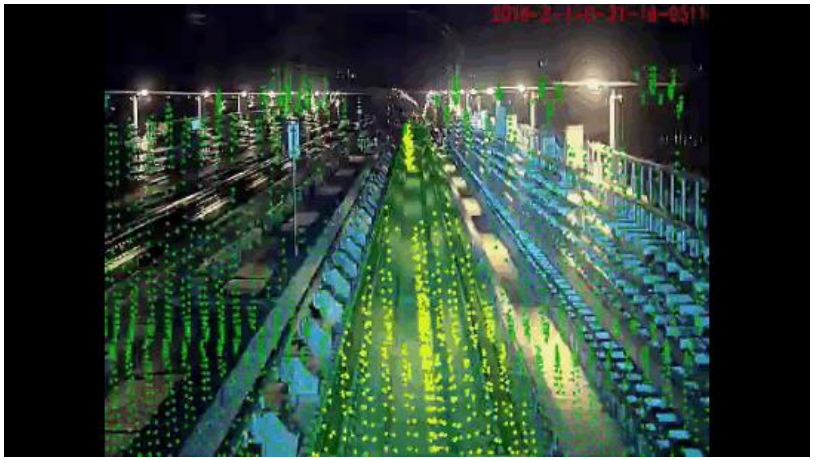
KW

Examples: Sensor Fusion of Lidar and Camera

- Cameras
  - + High resolution
  - + Distinguish colors
  - – Sensitive to light conditions
  - – No distance measurement
- Lidar
  - + 360* field of view
  - + Distance measurement
  - – Cannot distinguish colors
  - – Limited object classification
- Sensor Fusion
  - Compensate disadvantages
  - Improve robustness/accuracy



Strad Vision



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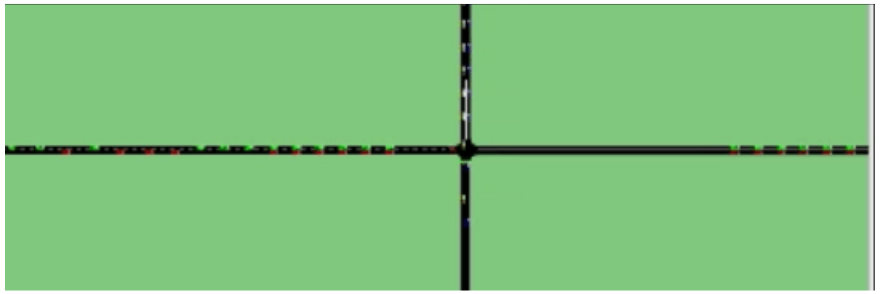
Examples: V2X Communication

- CAVs
  - On-board units (OBUs)
  - Road-side units (RSUs)
  - Safety warnings
  - Traffic management
  - Coordination (future)
- ATs
  - Communications-based train control (CBTC)
  - Moving block signaling
- Conclusion
  - Different technologies
  - Different applications



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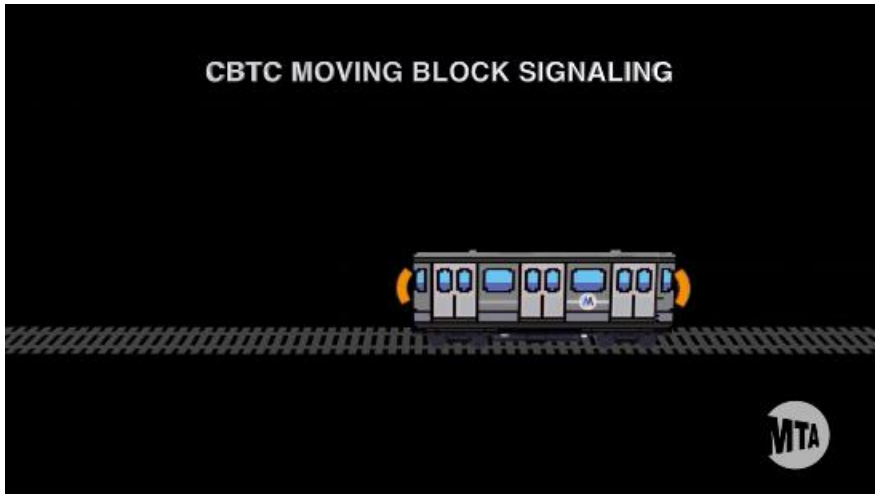
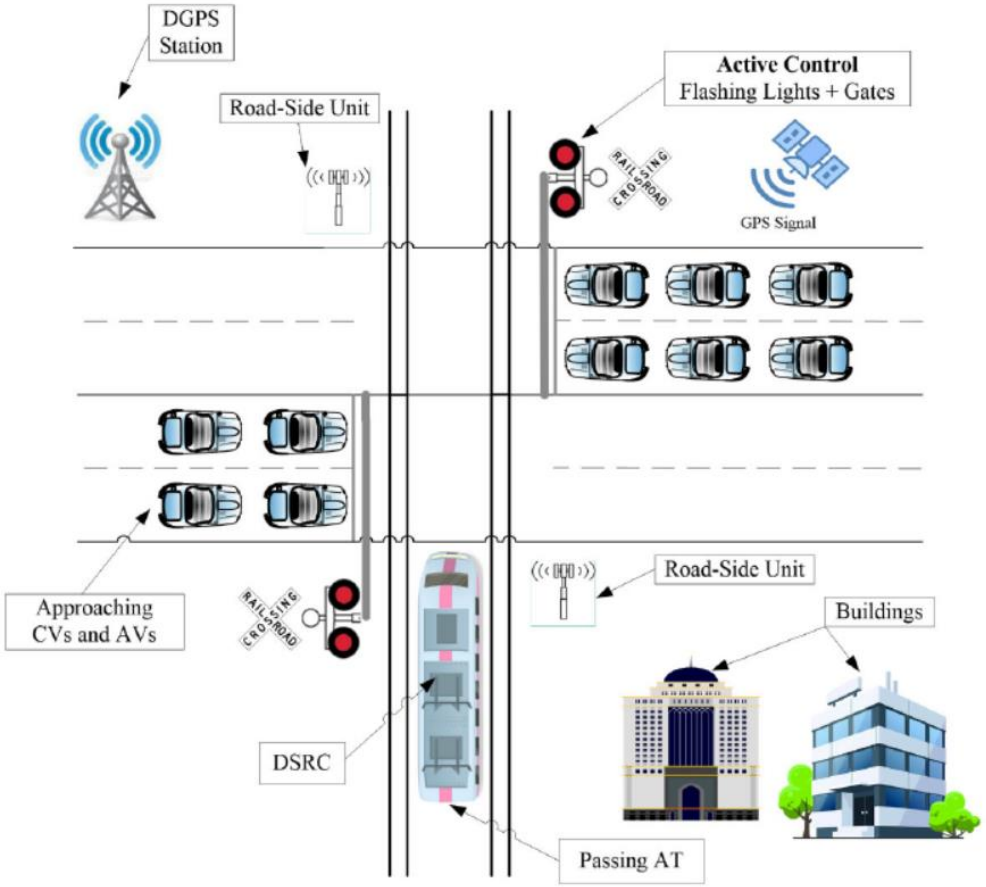


MTAinfo

Examples: Intersection between the Two Worlds

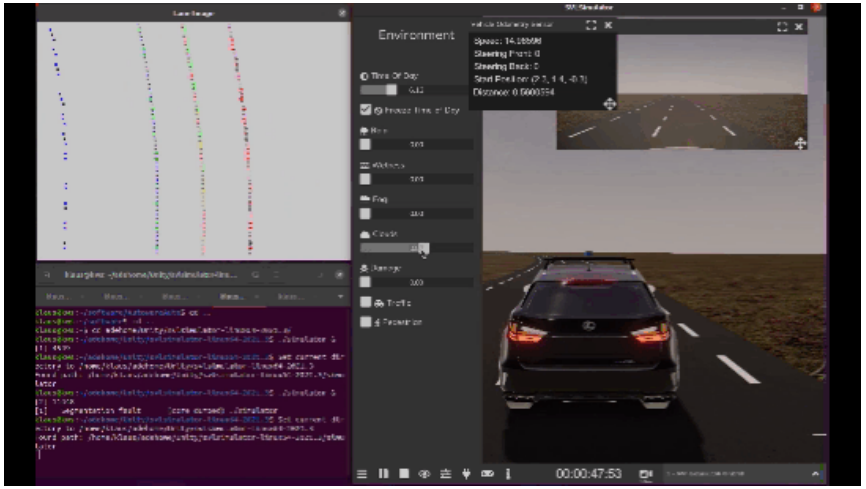
- Highway-rail Grade Crossing
  - CAVs communicate with RSUs
  - ATs communication with GSM-R
- Required Integration
  - Provide approaching train information to RSUs
  - Provide CAV traffic information to train communication system



Examples: Simulation-based Tests

- Model-in-the-Loop
  - System model is simulated
  - Software code model is simulated
- Software-in-the-Loop
  - System is modeled
  - Software-code is simulated
- Hardware-in-the-Loop
  - System model is simulated in real time
  - Software code is deployed on real hardware

⇒ **Also required for ATs**



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Open Rails

Summary

- Corresponding Problems
  - Object detection
  - Localization
  - Safety warnings and measures
  - Traffic management
- Corresponding Technologies
  - Sensors and sensor processing
  - Sensor fusion
  - Integration of CBTC and V2X communication system
  - Simulation-based testing on different levels

THANK YOU FOR YOUR ATTENTION!

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