Horizon 2020
European Union Funding
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A Vision of Intelligent Train Control

Francesco Flammini[1,2], Lorenzo De Donato[3], Alessandro Fantechi[4], Valeria Vittorini[3]

1. Mälardalen University, Sweden
2. Linnaeus University, Sweden
3. University of Naples Federico II, Italy
4. University of Florence, Italy

Presentation Outline

- Context: The RAILS Project
- Base Concepts and Current Train Control Systems
- AI Challenges in Autonomous Trains
- Towards Intelligent Train Control

Roadmaps for AI integration in the raiL Sector

4 EU Partners | 10 AB Members | 2 Ph.D. Students

Activities

1 AB Meeting | **1 Survey**

KoM Meeting *(30/01/20)*
Mid-Term Work Shop *(25/02/22)*

RAILS Supported WS Series

AI4RAILS 2020
co-located with EDCC2020

AI4RAILS 2021
co-located with EURO2021

Upcoming

AI4RAILS 2022
co-located with EDCC22
Zaragoza, Spain
12 September 2022

Structure

WP6: Project Management

DISCOVERY

WP1: State-of-the-Art of AI in the Railway Transport

ASSESS

WP2: AI for Rail Safety and Automation
WP3: AI for Predictive Maintenance and Defect Detection
WP4: AI for Traffic Planning and Management

LEARN

WP5: Dissemination and Future Roadmaps

Published Deliverables

https://rails-project.eu/downloads/deliverables

D1.1: Definition of a reference taxonomy of AI in railways.
D1.2: Summary of existing relevant projects and state-of-the-art of AI application in railways.
D1.3: Application Areas (including guidelines, survey results, and recommendations).
D2.1, **D3.1**, and **D4.1** which are "Reports on case studies and analysis of transferability from other sectors" in the context of WP2, WP3, and WP4 respectivel.

Talks & Presentations

- IEEE ITCS 2020
- InnoRail 2021
- DisCoRail 2021
- RSSRail 2022
- INFORMS 2021

Upcoming

- WCRR 2022

Papers & Articles

- ✓ Roadmaps for AI Integration in the Rail Sector – RAILS (ERCIM News 121)
- ✓ A Systematic Review of Artificial Intelligence Public Datasets for Railway Applications (MDPI Infrastructures)
- ✓ A Systematic Review of Artificial Intelligence Public Datasets for Railway Applications (MDPI Infrastructures)
- ✓ Software Verification and Validation of Safe Autonomous Cars: A Systematic Literature Review (IEEE Access)
- ✓ Artificial Intelligence in Railway Transport: Taxonomy, Regulations and Applications (IEEE Transactions on ITS)
- ✓ A Literature Review of Artificial Intelligence Applications in Railway Systems (Transportation Research Part C: Emerging Technologies)
- ✓ A vision of Intelligent Train Control (RSSRail 2022 - Lecture Notes in Computer Science)
- ✓ Trustworthy AI for safe autonomy of smart railways: directions and lessons learnt from other sectors (WCRR 2022)

https://rails-project.eu/ | RAILS S2R Project | @project_rails

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Automation, Autonomy, and the Role of AI

Automation

Ability of a system to automatically or semi-automatically (i.e., without or with partial human intervention) perform a given task basing on pre-specified rules.

Autonomy *(extends the Automation concept)*

Ability of a system to dynamically adapt to unexpected scenarios by taking independent decisions.

Role of AI

To make vehicles capable of learning from the experience and taking autonomous decisions to adapt to changes in the environment.

Background on Current Train Control Systems

Automatic Train Management Functions

Automatic Train Operation	**ATO**	Automatically drive the train and stop at stations when needed.
Automatic Train Protection	**ATP**	Automatically protect the train by applying brakes when needed.
Automatic Train Control	**ATC**	Both ATP and ATO are in place to ensure full control of the train.
Automatic Train Supervision	**ATS**	Manage train schedule and coordinate routes along whole tracks.

Grade of Automation (GoA) Levels

GoA 0	Train operations are manually supervised by the driver, no automation.
GoA 1	Train operations are manually supervised by the driver supported by ATP.
GoA 2	Semi-automatic train operation. ATO and ATP systems automatically manage train operations and protection while supervised by the driver.
GoA 3	Driverless train operation with on-board staff handling possible emergencies.
GoA 4	Unattended train operation, neither the driver nor the staff are required.

Segregated and Open Railway Environments

Segregated Environments
(e.g., metro lines with platform screen doors)
- Isolated from external factors -

- ATO currently deployed as part of CBTC
- Driverless Metros – High GoA till 4

Open Environments
(e.g., high speed, urban/suburban lines)
- Not isolated from external factors -

- ATO integration still experimental
- ATO over ETCS (AoE) – GoA2 (initially)

AI Challenges in Autonomous Trains

AI { ❖ Improve Perception ❖ Improve Driving Decisions } **Safety-critical functionalities**

Certification Challenges for AI

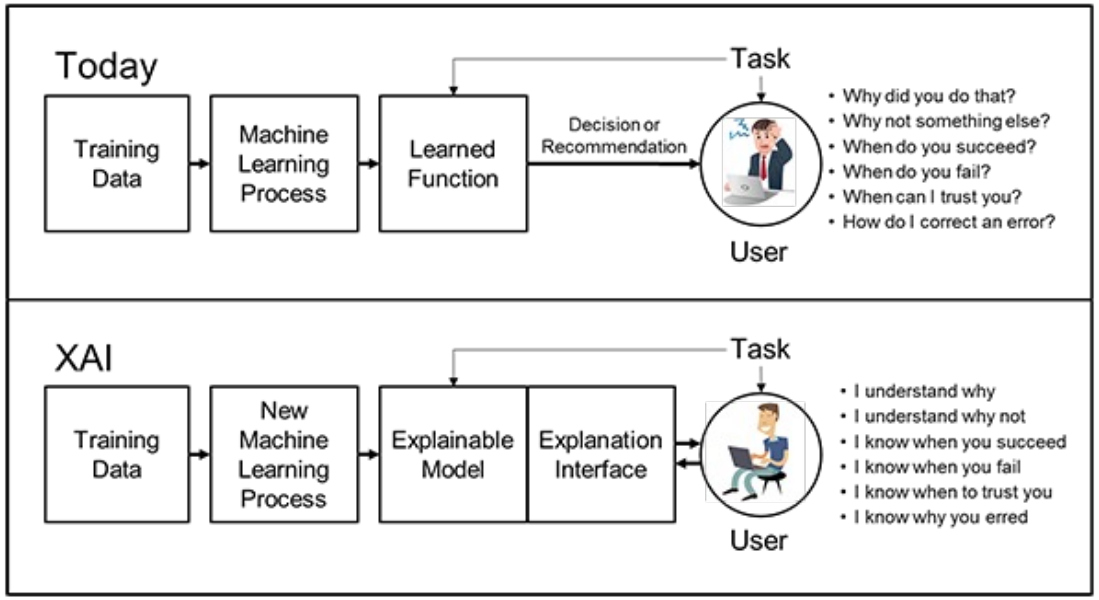
(particularly for DL systems)

Stability **Explainability**

Possible solution:

Define safety boundaries for AI operation

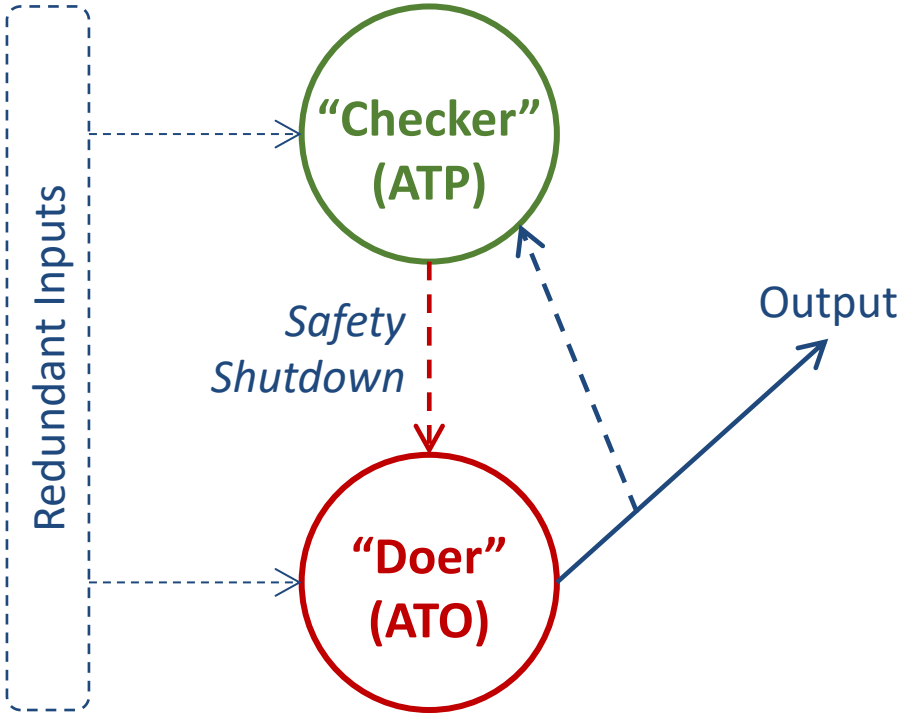
Explainable AI (XAI)



https://www.darpa.mil/program/explainable-artificial-intelligence

Example of Safety Envelope

- High SIL required
- Responsible for safety
- Implements failsafe



- Low SIL is acceptable
- Implements driving functionalities

ATO: performs an action that would bring the system into an ***unsafe state***

ATP: blocks the action and brings the system into a ***failsafe state***

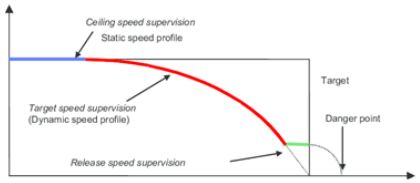
Koopman, P., Wagner, M., "Toward a framework for highly automated vehicle safety validation", SAE Technical Paper, 2018.

Vision of Intelligent Train Control

***A**utomatic **T**rain **P**rotection*

acting as a SAFETY ENVELOPE to ATO/ITO by ensuring train interdistance, train and route integrity, etc.

Requires connection with signalling system



SIL4

Energy Optimisation

Capacity Optimisation

Comfort Optimisation

***I**ntelligent **T**rain **O**peration*

adding ”smartness”, learning and adaptation to traditional ***A**utomatic **T**rain **O**peration*

ATP unavailability or partial supervision

***I**ntelligent **T**rain **P**rotection*

using AI to replace/support ATP

SIL?

Obstacle Detection

Signal Recognition

Grades of Intelligence

*where present

GoI 1

This level includes ATC implementations where AI is not used or it is used for limited functions such as optimisation within ATS. That means *limited or no autonomy* is normally possible in open environments.

GoI 2

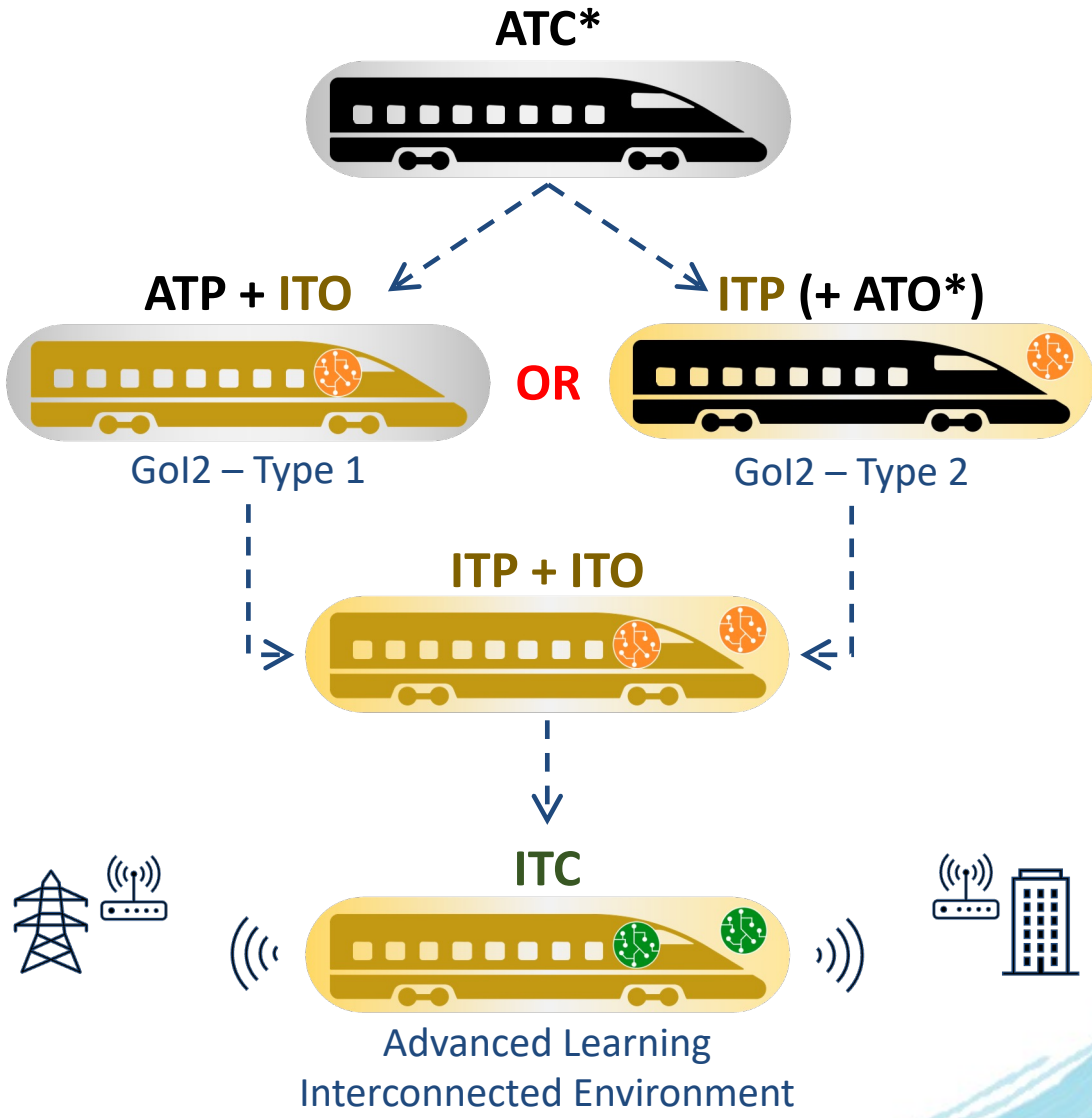
This level supports partial autonomy in open environments, by including *only ITO* as an adaptive ATO with energy, capacity and/or comfort optimisation capabilities, *or only ITP* for driving assistance and/or as a low-speed backup system in case of ATP unavailability or limited supervision.

GoI 3

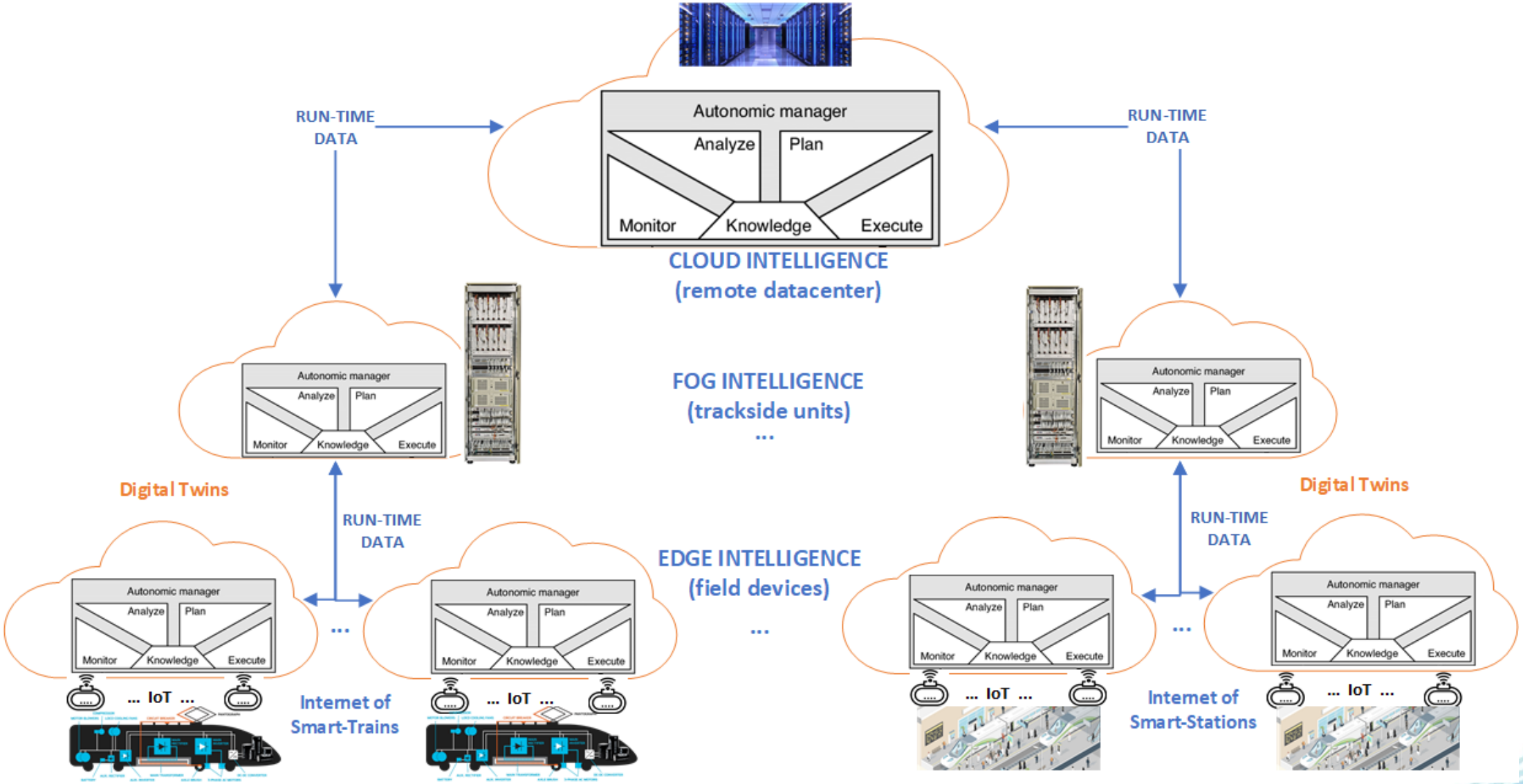
This level includes *both ITO and ITP*, allowing for full autonomy even in open environments, although *with no advanced learning and adaptation capabilities*. For instance, at GoI3, the artificial vision algorithms of ITP can be trained only once, e.g. to detect on-track obstacles, and never updated.

GoI 4

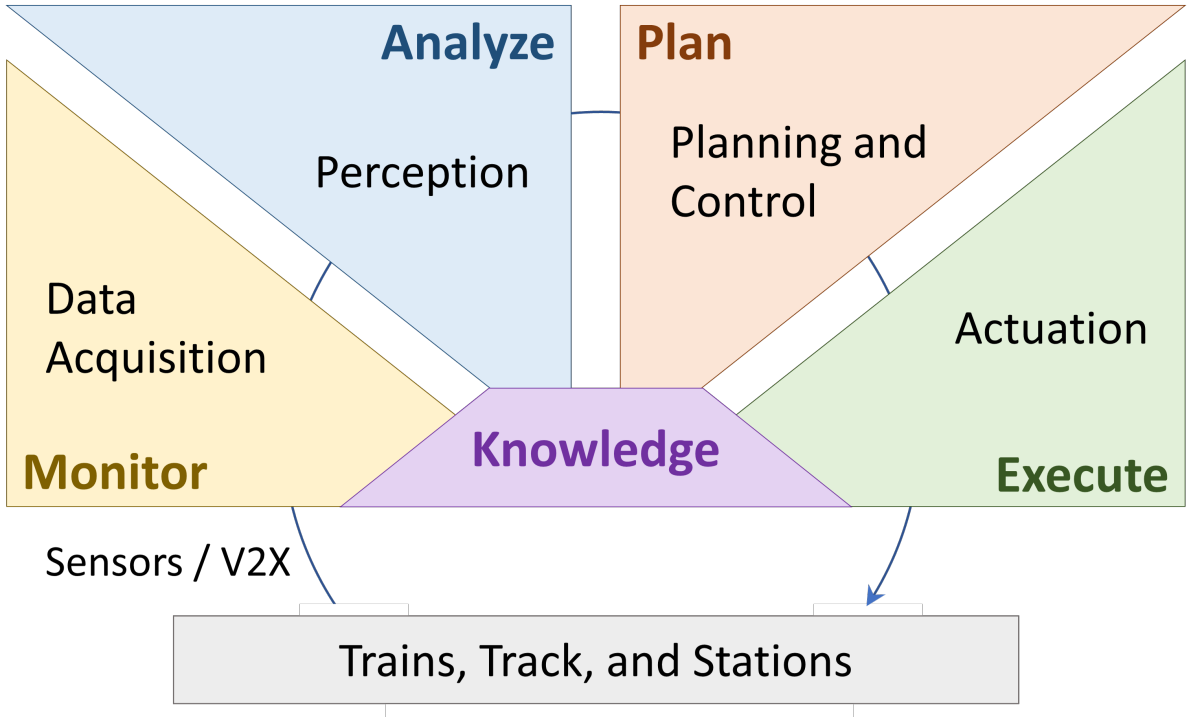
This level includes *both ITO and ITP*, allowing for full autonomy in all environments, *with advanced learning and adaptation capabilities, such as unsupervised and reinforcement learning*. The system is typically *fully connected*, dynamically updated, and supported by higher levels of fog/cloud intelligence by using external AI models for big data analytics, such as those enabled by digital twins.



Levels of Intelligence in Railway Control and Supervision



MAPE-K Loop for Intelligent Train Control



Conclusions

Challenges

In case AI will be in charge of managing the safety of the whole system, among others, they would be required:

- ❖ Well-defined certification processes
- ❖ Mechanisms incrementing situation awareness
- ❖ Monitoring mechanisms

Directions

For the fast take up of AI in Autonomous Train Driving:

- ❖ (Deep) Reinforcement Learning & Federated Learning
- ❖ Advanced Train Driving Simulators
- ❖ (Cognitive) Digital Twins

Thank you for your attention!

Lorenzo De Donato: lorenzo.dedonato@unina.it

RAILS Roadmaps for AI Integration in raiL Sector

https://rails-project.eu/

RAILS S2R Project

@project_rails

https://www.researchgate.net/project/RAILS-Roadmaps-for-AI-integration-in-the-raiL-Sector-EU-Horizon-2020-Shift2Rail-JU