WP3

Predictive Maintenance and Defect Detection

General Recommendations

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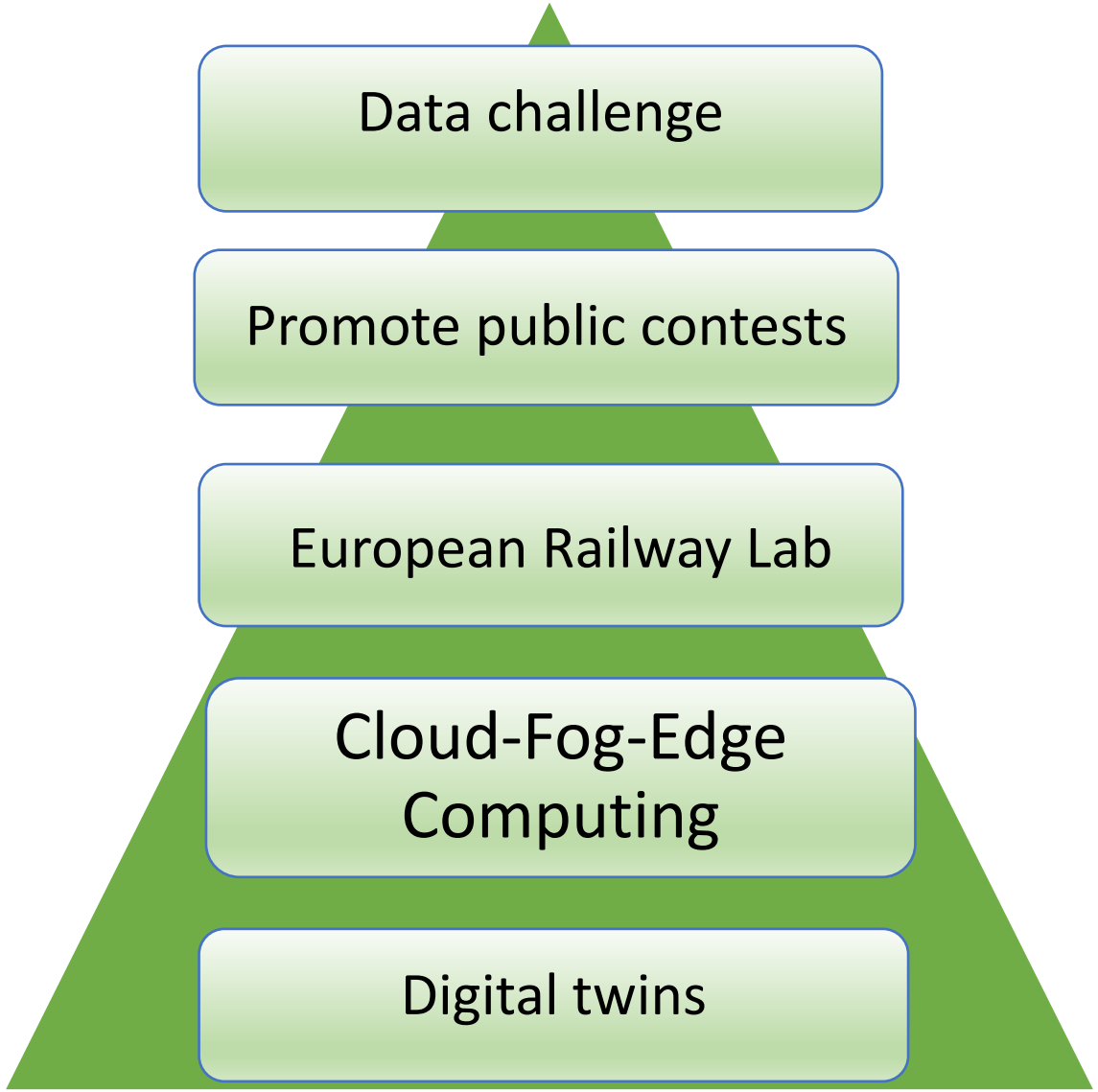
WP3 General Recommendations



Data challenge

- Complex data challenge with no gold solutions.
- Two interventions:

1. A structural solution to data availability
   a) Maintain a collection of public datasets in railways.
   b) Build a Common Conceptual Data Model for classes of railway applications (existing EU-RAIL: LINX4RAIL and LINX4RAIL-2)
   c) Develop standards for datasets to be used in AI application.
   d) Establish Consortia for data utilisation
      - Data sharing: Build a shared railway database for training and testing AI models. Work underway in the TAURO project.
      - Model sharing: Train AI models on confidential proprietary data and share the trained models instead of the data. Strategies include adopting various technologies and approaches:
        - Federated Learning, Secure multiparty, Distributed Ledgers and Blockchain

Data challenge (cont'd)

2. Coping with limited data
   a) Generating Synthetic Data from Scratch:
      - Real-life simulators (e.g., GTA V) or 3D editors and scenario simulators
      - Usage of Digital Twins
   b) Extending existing datasets.(e.g., cropping, stretching, GANs)
   c) Leveraging existing knowledge, e.g., Transfer Learning

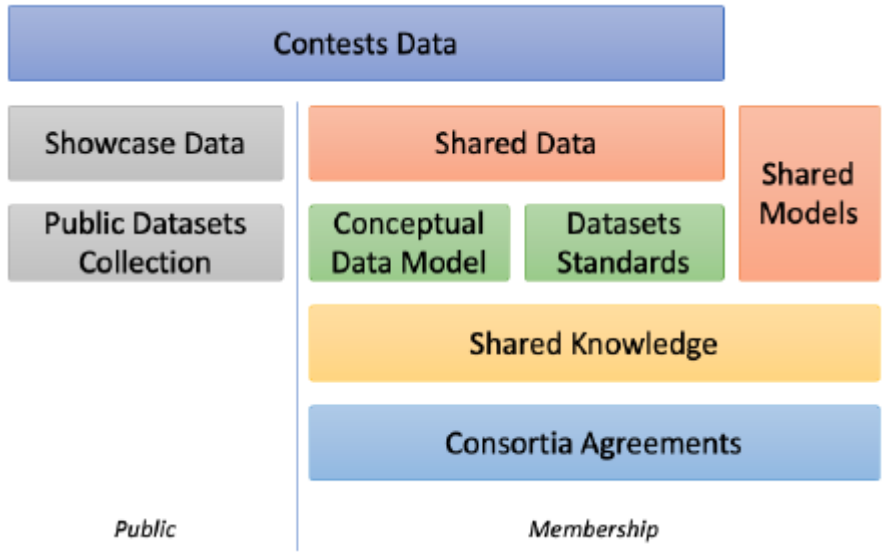
- Quality of synthetic data must be evaluated
  - Conduct experimental campaign to assess technique usage in railways.
  - Evaluate datasets for utility and correlation with real events/scenes.

Promote public contests based on selected case studies and benchmarks

- Fast AI Adoption:
  - Emulate successful competitions (e.g., MS COCO, ImageNet, RailSem19).
- Overcome Data Challenges:
  - Generate synthetic datasets to address data privacy concerns.
- Define Effective Challenges:
  - Expert-defined requirements and constraints.
  - Reflect challenge characteristics in datasets.
- Drive Advancements:
  - Learn from achievements in AI competitions.
  - Promote AI-powered technology advancements.

European Railway Lab for AI application

- Vision: A collaborative space fostering investigation and adoption of AI-powered solutions in rail transportation.
- Collaboration: Railway players (industries, operators, research communities) form alliances (consortia) to share knowledge, data, and models.
- Activities: Various activities for the general public and laboratory members, promoting investigation and research.
- Joining Alliances: Members can join alliances based on objectives and information sharing capabilities.
- Data and Model Sharing: Achievable through a conceptual data model and dataset construction standards



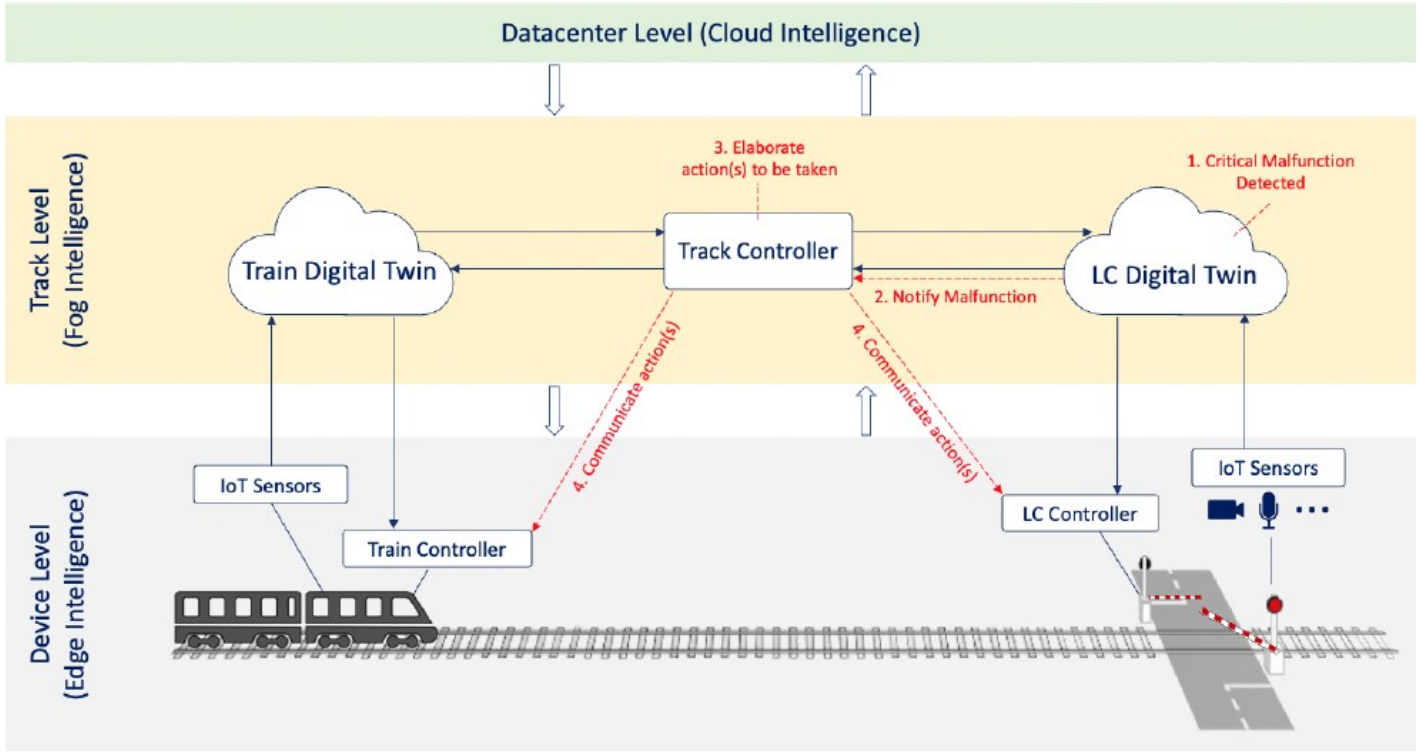
A data-centric view of an AI-lab for joint research in railways

Exploit Cloud-Fog-Edge Computing Paradigms

- Data collection and processing across IoT devices to the cloud enhance AI for maintenance and planning in railways.
- Cloud, fog, and edge computing optimize railway asset monitoring, safety, and Digital Twin integration.
- Data flows from Edge Level (onboard sensors) to Fog Level (cluster monitoring) and Cloud Level (large-scale storage and computing).
- Distributed intelligence enables event management, system optimization, and maintenance planning.
- Practical implementation requires addressing challenges and transitioning to a multi-tenant model.

Digital Twins: opportunities

- Digital Twins offer real-time monitoring and analysis of railway assets
  - Cognitive Digital Twins (CDTs) enable predictive analyses and AI model training
  - Integration of Digital Twins with distributed intelligence levels enhances system protection
- Example: left figure



Integrating DTs and Levels of Intelligence to Ensure Protection in Case of LC Failure [1]

[1] RAILS, "Deliverable 3.2 – WP3 Report on AI approaches and models," 2022. [Online]. Available: https://rails-project.eu/downloads/deliverables/

Digital Twins: Challenges

[1] R. Dirnfeld, L. De Donato, F. Flammini, M. S. Azari, and V. Vittorini, “Railway digital twins and artificial intelligence: Challenges and design guidelines,” in Dependable Computing–EDCC 2022 Workshops: SERENE, DREAMS, AI4RAILS, Zaragoza, Spain, September 12, 2022, Proceedings. Springer, 2022, pp. 102–113.

- Digital Twins offer real-time monitoring and analysis of railway assets
  - Cognitive Digital Twins enable predictive analyses and AI model training
  - Integration of Digital Twins with distributed intelligence levels enhances system protection
- Challenges:
  - Guidelines for DT generation and integration of AI functionalities are missing
  - We have developed formalized steps [1] to guide DT realization.
  - Key areas for improvement
    - Establish reference standards for DT development.
    - Develop procedures for (semi-)automatic DT generation

Thank you for your attention!