



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee^{PhD}
information technology
electrical engineering



DIE
TI

UNI
NA

Lorenzo De Donato

Artificial Intelligence techniques for rail dependability and automation

Tutor: Prof. Valeria Vittorini

co-Tutors: Prof. Carlo Sansone,

Prof. Francesco Flammini (Linnaeus University, Sweden)

Cycle: XXXVI

Year: First

My background

- **MSc degree:** Computer Engineering
- **Research group/laboratory:**
 - Laboratorio Sicurezza Sistemi Informativi (SECLAB)
 - Pattern analysis and Intelligent Computation for mUltimedia Systems (PICUS)
- **PhD start date:** 1st November 2020
- **Scholarship type:** funded by CINI, partially on the H2020 Shift2Rail RAILS project

Collaborations

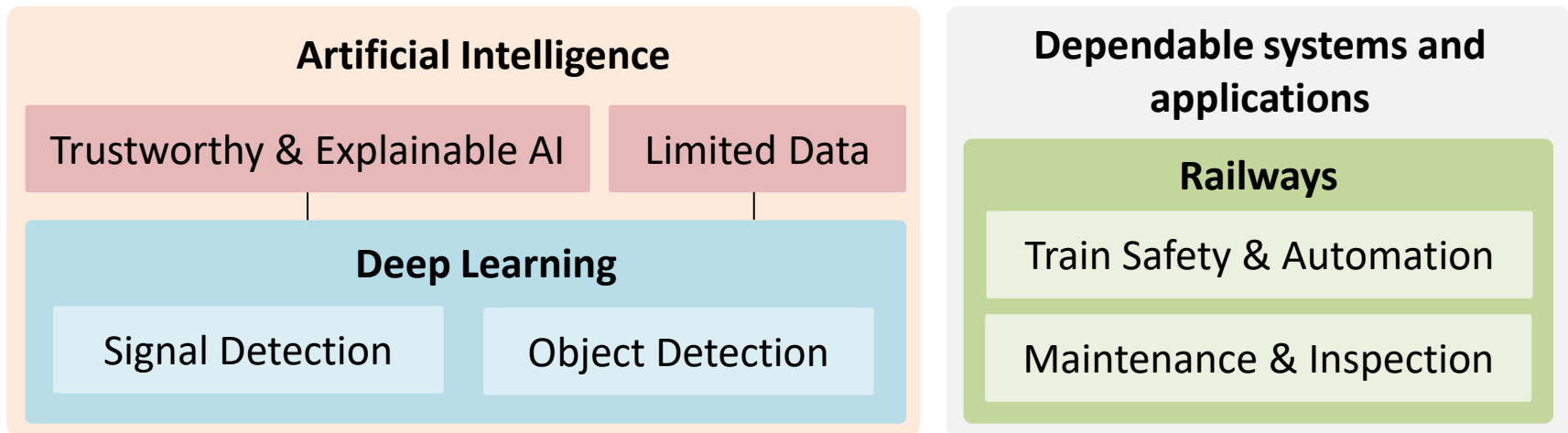
Context: H2020 Shift2Rail RAILS (Roadmaps for AI integration in the rail Sector) project.



Research field of interest

Investigate the potential of Artificial Intelligence (AI) approaches in the rail sector and contribute to the definition of roadmaps for future research in train safety and automation and railways maintenance and inspection.

My research area



Summary of study activities

- Study on:**
- Application of AI in railways and transferability from other sectors
 - AI Trustworthiness, Ethics, and Regulations
 - Deep Learning for Signal and Object Detection

Activity Type	Title	Motivation
<i>Ad hoc PhD courses</i>	“Scientific Programming and Visualization with Python”; “Digital Forensics’ methods, practices and tools”; “Cambridge Assessment English: C1 Advanced” (CLA)	General skills
	“Stochastic Modelling” (MERC)	Systems modelling and understanding
<i>MSc courses</i>	“Neural networks and deep learning”	DL techniques
<i>Seminars</i>	“EU’s AI Policy & Regulation: How can SMEs and Start-Ups test the trustworthiness of the AI applications”; “MONDAIS - AI for safety-critical systems”; “Pie & AI: Edinburgh - Breaking into AI”; “Privacy Preserving AI”	AI Trustworthiness, Ethics, and Regulations
	“Patent Searching Best Practices with IEEE Xplore”; “IEEE Authorship and Open Access Symposium: Best Practices to Get Published to Increase the Exposure and Impact of Your Research”	General skills
	“Risk assessment in real life: experiences from the railway domain”	Systems modelling and understanding
<i>Conferences</i>	“IEEE Rising Stars Global 2021”, Virtual, 2-4 January 2021	General skills

Research activity: Overview

Activity 1

Problem: Identification of current and potential application areas of AI in railways.

Objective: Assessment of AI adoption in railways.

Methodology: Summary of existing relevant projects and state-of-the-art of AI application in railways.



Activity 2

Problem: Obstacle Detection for Intelligent Train Operation and Level Crossings Remaining Useful Life estimation and health monitoring.

Objectives:

- Transferability analysis from other sectors.
- Identification of pilot case studies.
- Development of proofs-of-concept specifically based on Deep Learning for real-world scenarios.

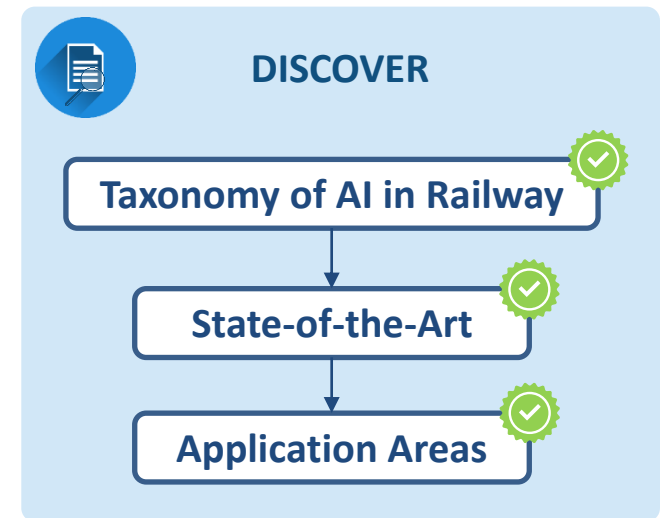
Methodology:

- Definition of a framework for transferability analysis.
- Investigation of dependable AI approaches.
- Exploitation of solutions based on data augmentation or transfer learning to cope with limited data.

Concluded Research activities

1. *Assessment of AI adoption in railways.*

- Projects analysis, with particular emphasis on S2R projects.
- Review of research papers, with particular emphasis on the “maintenance and inspection” sub-field.
 - SLR aimed at Deep Learning Applications leveraging audio and video data for railway maintenance purposes.
- Definition of preliminary challenges and opportunities of AI in railways.



2. *Identification of Application Areas* based on the previous activity and suggestions from railway stakeholders and research centres.

- Definition of relevant railway problems and preliminary guidelines to select the most suitable AI approach.
- Identification of urgent issues to be faced for safe and effective adoption of AI in railways (e.g. trustworthiness concerns, limited data, regulations) and high impact areas.

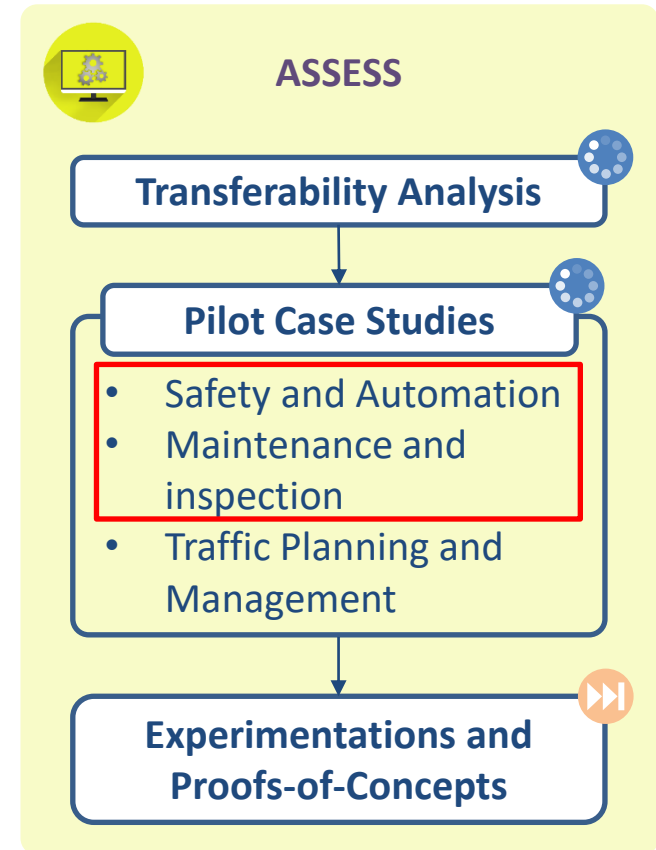
Ongoing Research activities

1. *Analysis of transferability from other sectors, focusing more on “maintenance and inspection” than on “train safety and automation”.*

- Investigation of AI-based solutions within UAVs, manufacturing, machinery, and critical infrastructures.
- Preliminary identification of promising AI approaches to be transferred based on a transferability framework.

Identification of pilot case studies including, among others:

- Level Crossings Remaining Useful Life estimation and health monitoring.
- Obstacle Detection for Intelligent Train Operation.



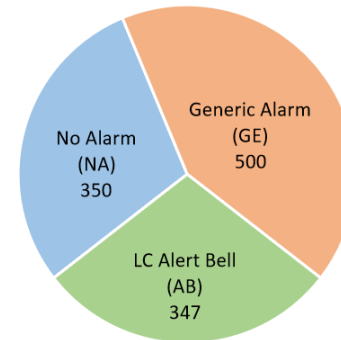
Addressed Case Study

Problem (as from my master's thesis):
Recognition of the Level Crossing Alert Bell signal.

Methodology: Reuse the knowledge gained to solve a similar task (transfer learning) by exploiting a CNN, named VGGish, for which pre-trained weights were made available.

Improvements: A new class was added, thus additional samples were collected, to also perform audio signal detection.

Future improvements: on-field testing and decibel-to-distance analyses.



1197 audios
(WAV format, 10s)

		<i>Frame-level</i>			<i>Audio-level</i>		
		<i>AB</i>	<i>NA</i>	<i>GE</i>	<i>AB</i>	<i>NA</i>	<i>GE</i>
<i>Pred.</i>	<i>AB</i>	414	10	50	44	0	2
	<i>NA</i>	9	430	40	0	44	2
	<i>GE</i>	27	10	530	1	1	61
<i>Precision</i>		92,00	95,56	85,48	97,77	97,77	93,84
<i>Recall</i>		87,34	87,34	93,47	95,65	95,65	96,82
<i>F1-Score</i>		89,61	92,57	89,30	96,70	96,70	95,31

Classification Accuracy

Frame-level: 90,39%

Audio-level: 96,13%

Products

[D1]	Nikola Bešinović, Ruifan Tang, Zhiyuan Lin, Zhiyuan Lin, Tianli Tang, Lorenzo De Donato, Valeria Vittorini, Ziyulong Wang, Francesco Flammini, Mauro José Pappaterra, Rob M.P. Goverde, “Deliverable D1.2: Summary of existing relevant projects and state-of-the-art of AI application in railways”, 2021 (Published)
[D2]	Stefano Marrone, Lorenzo De Donato, Valeria Vittorini, Roberto Nardone, Ruifan Tang, Nikola Bešinović, Francesco Flammini, Rob M.P. Goverde, Zhiyuan Lin, “Deliverable D1.3: Application Areas”, 2021 (Published)
[P1]	Lorenzo De Donato, Francesco Flammini, Stefano Marrone, Claudio Mazzariello, Roberto Nardone, Carlo Sansone, and Valeria Vittorini, “A Survey of Deep Learning Applications to Railway Maintenance by Audio-Video Analytics”, IEEE Transactions on Intelligent Transportation Systems, 2021 (Submitted)
[P2]	Nikola Bešinović, Lorenzo De Donato, Francesco Flammini, Rob M.P. Goverde, Zhiyuan Lin, Ronghui Liu, Stefano Marrone, Roberto Nardone, Tianli Tang, and Valeria Vittorini, “Artificial Intelligence in Railway Transport: Taxonomy, Regulations and Applications”, IEEE Transactions on Intelligent Transportation Systems, 2021 (Submitted)
[P3]	Ruifan Tang, Lorenzo De Donato, Nikola Bešinović, Francesco Flammini, Rob M.P. Goverde, Zhiyuan Lin, Ronghui Liu, Tianli Tang, Valeria Vittorini, and Ziyulong Wang, “A Literature Review of Artificial Intelligence Applications in Railway Systems”, Transportation Research Part C: Emerging Technologies, 2021 (Submitted)

D – RAILS Deliverable; P – Journal Paper

Next Year

Research activities:

Experimentation and development of proofs-of-concept related to:

- DL-based Level Crossings Remaining Useful Life estimation and health monitoring.
- Obstacle Detection for Intelligent Train Operation.

With focus on:

- Trustworthy and dependable AI approaches.
- Transfer Learning or data augmentation techniques to cope with limited data.

Dissemination and Communication activities as RAILS

Ambassador:

Upcoming event: *“INNORAIL 2021: Future of the railway – Railway of the Future”*, Budapest, 16-18 November 2021.