PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

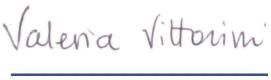
PhD Student: Lorenzo De Donato

Cycle: XXXVI

Training and Research Activities Report

Year: First

Tutor: prof. Valeria Vittorini



Co-Tutors: prof. Carlo Sansone, prof. Francesco Flammini (Linnaeus University, Sweden)

Date: October 28, 2021

1. Information:

- **PhD student: Lorenzo De Donato**
- **DR number: DR995134**
- **Date of birth: 06/07/1993**
- **Master Science degree: Computer Engineering**
  University: Università degli Studi di Napoli "Federico II"
- **Doctoral Cycle: XXXVI**
- **Scholarship type:** ***funded by CINI (Consorzio Interuniversitario Nazionale per l'Informatica), partially on the H2020 Shift2Rail RAILS project***
- **Tutor: prof. Valeria Vittorini**
- **Co-tutors: prof. Carlo Sansone, prof. Francesco Flammini (Linnaeus University, Sweden)**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Digital Forensics' methods, practices and tools	**Course**	**10**	**3**	**03/11/2020 - 10/11/2020**	**Dr. Giovanni Cozzolino (DIETI)**	**Y**
Stochastic Modelling	**Course**	**24**	**6**	**10/11/2020 - 17/12/2020**	**Prof. Massimiliano Giorgio (MERC)**	**Y**
AI4NETS - AI/ML for data communication Networks	**Seminar**	**3**	**0.6**	**02/11/2020**	**Politecnico di Milano jointly with Fondazione Politecnico di Milano**	**Y**
"#andràtuttobene: Images, Texts, Emojis & Geodata in a Sentiment Analysis Pipeline	**Seminar**	**1.5**	**0.3**	**25/11/2020**	**Prof. Flora Amato (DIETI), Prof. Giuseppe Longo (Fisica "Ettore Pancini")**	**Y**
Patent Searching Best Practices with IEEE Xplore	**Seminar**	**1**	**0.2**	**27/11/2020**	**IEEE**	**Y**
How to Get Published with IEEE	**Seminar**	**1.5**	**0.3**	**02/12/2020**	**IEEE**	**Y**
Artificial Intelligence Between Research	**Seminar**	**1.5**	**0.3**	**07/12/2020**	**The Consulate**	**Y**

and Industry					**General of Italy for Scotland and Norther Ireland, the Italian Institute of Culture in Edinburgh and the Scotland Office of the Italian Chamber of Commerce and Industry for the UK in collaboration with the University of Glasgow**	
Cybercrime and e-evidence: the criminal justice response	**Seminar**	**1**	**0.2**	**20/01/2021**	**Prof. Flora Amato (DIETI), Prof. Giuseppe Longo (Fisica "Ettore Pancini")**	**Y**
Machine Learning: causality lost in translation	**Seminar**	**1.5**	**0.3**	**10/02/2021**	**Prof. Flora Amato (DIETI), Prof. Giuseppe Longo (Fisica "Ettore Pancini")**	**Y**
EU's AI Policy & Regulation: How can SMEs and Start-Ups test the	**Seminar**	**1**	**0.2**	**17/02/2021**	**Carmen Mac Williams (Grassroot**	**Y**

trustworthiness of the AI applications					**s Arts)**	
Scientific Programming and Visualization with Python	**Course**	**18**	**2**	**08/03/2021 - 10/03/2021**	**DiSt departmen t - Scuola Politecnica e delle Scienze di Base**	**Y**
MONDAIS - AI for safety-critical systems	**Seminar**	**1.5**	**0.3**	**01/03/2021**	**datascience .aero (https://dat ascience.ae ro/about)**	**N**
Pie & AI: Edinburgh - Breaking into AI	**Seminar**	**1**	**0.2**	**01/03/2021**	**DeepLearn ing.AI community (hosted by Dr Mahdi Torabi)**	**N**
Cambridge Assessment English: C1 Advanced (CAE)	**Course**	**60**	**6**	**02/03/2021 - 28/05/2021**	**Centro Linguistico di Ateneo**	**Y**
Modelling the Complexity of Multiagent Activity for Human-AI Interaction using Dynamical Primitives	**Seminar**	**1.5**	**0.3**	**06/05/2021**	**Scuola Superiore Meridional e**	**Y**
Risk assessment in real life: experiences from the railway domain	**Seminar**	**1.5**	**0.3**	**26/05/2021**	**Prof. Valeria Vittorini (DIETI)**	**Y**
Aerospace Cyber-Physical Systems: Towards Trusted Autonomous Air and Space Operations	**Seminar**	**1**	**0.2**	**18/06/2021**	**IEEE SMC Society Italy Chapter of the Italian Section (Chair: Prof. G. Fortino) jointly with IEEE ASP AESS (Chair: Prof. R. Sabatini)**	**N**

Neural networks and deep learning	**Course**	**48**	**6**	**08/03/2021 - 09/06/2021**	**Prof. Roberto Prevete (DIETI)**	**Y**
On the synthesis and crowdsourcing of control policies for autonomous agents from data	**Seminar**	**1**	**0.2**	**01/07/2021**	**Scuola Superiore Meridionale**	**Y**
L'esposizione ai campi elettromagnetici generati dal sistema 5G - Metodologie scalari e vettoriali di misura dell'esposizione e tecniche di estrapolazione	**Seminar**	**4**	**0.8**	**16/07/21**	**Prof. Nicola Pasquino (DIETI)**	**Y**
How to Publish Open Access with IEEE to Increase the Exposure and Impact of Your Research	**Seminar**	**1.5**	**0.3**	**29/09/2021**	**IEEE**	**Y**
Privacy Preserving AI	**Seminar**	**1**	**0.2**	**05/10/2021**	**Massachusetts Institute of Technology**	**N**
Efficient Computing for Deep Learning	**Seminar**	**1**	**0.2**	**08/10/2021**	**Massachusetts Institute of Technology**	**N**

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**9**	**1.7**	**5**	**0**	**15.7**
Bimonth 2	**0**	**0.7**	**6**	**0**	**6.7**
Bimonth 3	**2**	**0.5**	**6**	**0**	**8.5**
Bimonth 4	**6**	**0.8**	**6**	**0**	**12.8**
Bimonth 5	**6**	**1**	**3**	**0**	**10**
Bimonth 6	**0**	**0.7**	**6**	**0**	**6.7**
Total	**23**	**5.4**	**32**	**0**	**60.4**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 - 4.8**	

3. Research activity:

Most of the research activities I carried out during this year have been conducted in the context of the H2020 Shift2Rail project RAILS (Roadmaps for AI integration in the raiL Sector), whose main objective is to investigate how to bring Artificial Intelligence (AI) approaches in the rail sector and provide recommendations for their implementation in railways applications. I have been involved in this project since its beginning and I have had the opportunity to cooperate with researchers (professors, lecturers, and PhD students) coming from Linnaeus University (Sweden), University of Leeds (United Kingdom), and Technische Universiteit Delft (Netherlands).
Therefore, my research activities, described below, have contributed to the advancement of most of the tasks of the RAILS project.

1. **Assessment of AI adoption in railways. (concluded)**
   The objective was to outline the state of integration of the AI techniques within the various subdomains of the rail sector addressed by the RAILS project, which can be clustered in three macro areas: “Train safety and automation”, “Maintenance and inspection”, and “Network management”. To this aim, a summary of existing relevant projects and state-of-the-art of AI applications in railways have been carried out. Then, challenging railway problems that could be solved more efficiently leveraging AI were preliminary identified, as well as future directions regarding both the potentials of AI and the main issues for the adoption of AI in railways. The latter encompasses data-related, trustworthiness, and regulation issues. My contribution to this work includes: i) the review of all relevant Shif2Rail projects and some of the projects conducted worldwide addressing AI in railways; ii) the analysis of state-of-the-art AI solutions related to the field of maintenance and inspection; iii) the outline and description of some of the most promising future directions and challenging issues that should be faced for a fast take up of AI in railways. This work has been performed by leveraging the outcome of [1] (document to which I collaborated during my master’s thesis internship) and its results are described in [2].
   Particular attention has been paid to the investigation of **Deep Learning applications leveraging audio and video data for railway maintenance purposes.** The constraint on the data type comes from the necessity to adopt non-intrusive sensors so as not to run into re-approval processes, especially when dealing with safety-critical systems. Therefore, I carried out a Systematic Literature Review according to well-known methodologies. The aim was to identify the most exploited state-of-the-art deep neural network and architectures (e.g. VGG, Faster R-CNN), the main railway maintenance tasks addressed (e.g. rail track surface defect detection, catenaries defect inspection), and open issues, challenges, and opportunities related to Deep Learning for railway maintenance applications. The latter includes small-scale object detection, multi-target applications, standardised datasets and benchmarks, and video and audio data combination. Scopus, IEEE Xplore, and ACM were used as source digital libraries. The results of this work are described in [3], which is still under revision.

2. **Identification of current and potential application areas of AI in railways. (concluded)**
   This research activity aimed at identifying current and potential application areas of AI across railway sub-domains, the main challenges to be faced for an effective take up of AI in railways, and some guidelines to drive the choice of appropriate AI approaches focusing on a particular aspect of the problem under analysis. To this aim, we leveraged the results coming from [2] and suggestions

from different railway stakeholders and research centres. In this context, I have contributed to: i) the realization of a picture of the current AI regulations; ii) the definition of relevant railway problems and preliminary guidelines to select the most suitable AI approach based on the problem that is intended to be addressed (e.g. classification, regression), the kind of available data (e.g. video, tabular), and the required model responsiveness (i.e. whether the model must operate in real-time or not); iii) the identification of application areas encompassing the urgent issues to be addressed for safe and effective adoption of AI in railways (e.g. trustworthiness concerns, limited data, regulations) and the high impact areas (i.e. scenarios in which AI-based applications could improve existing practices). The results of this work are described in [4], where also recommendations for future applications were outlined.

3. **Transferability analysis from other sectors. (ongoing)**
   A transferability analysis is being carried out to understand to what extent relevant AI applications in domains other than railways could be exploited to deal with railway problems. Therefore, a preliminary transferability framework was defined to identify promising AI-based solutions within both transport and non-transport sectors. Up to now, transport sectors included automotive, avionics, and maritime, while non-transport sectors included unmanned vehicles, manufacturing, machinery, and Critical Infrastructures (considering both cyber and physical concerns). My contribution to this work includes: i) the investigation of the AI-based applications developed within the unmanned aerial vehicles domain and the other non-transport sectors specified above; ii) the identification of AI-based applications proposed within the non-transport sectors that could be useful for maintenance and inspection activities in the railway; iii) a preliminary transferability study, in particular addressing the maintenance field. The results of these activities will be discussed in [5] and [6].

4. **Identification of pilot case studies**
   Based on all the activities described above, some pilot case studies have been identified, while others will be defined in the very near future, to lay the groundwork for experimentations and proofs-of-concept assessing the potentials of AI in railway. Among the outlined case studies, as future research activities, my work is expected to contribute to the development of proofs-of-concept for:
   - Deep Learning-based Level Crossings Remaining Useful Life (RUL) estimation and health monitoring (as a case study related to railway maintenance and inspection).
   - Obstacle Detection for Intelligent Train Operation (as a case study related to train safety and automation).

   Considering Level Crossings (LCs), it is possible to identify three macro subsystems: alert bell, traffic light (semaphore), and gate arm (bar). The idea is to design, in the future, an architecture composed of three modules each of which will focus on the RUL estimation or the health monitoring of one of the subsystems. Then, a fourth coordination module will implement the logic necessary to outline the status of the LC based on the outputs of the aforementioned modules. In continuity with the work carried out during my master's thesis internship, advancements have already been made towards the Level Crossing health monitoring based on Deep Learning approaches as described in the following.

5. **Deep Learning for Level Crossings health monitoring**
   A Deep Learning-based Level Crossing (LC) Alert Bell Detection System capable of classifying audio signals into "LC Alert Bell" or "Other Alarm" has been developed in the context of my master's thesis. An extended version has been realized during the first year to perform *audio signal* ***detection*** (i.e. to understand whether there is a sound activity or not) *besides the alarm classification*. Hence, this version includes three classes: i) LC Alert Bell; ii) Generic Alarm, which encompasses all the disturbing alarms such as emergency vehicles and car alarms; iii) No Alarm, which encompasses city and countryside background noises including passing cars and wind. At this aim, additional audio data were collected. The model is similar to its first version in terms of architecture implemented (a CNN named VGGish) and the exploited transfer learning approach. At this stage, in the test phase, the classification accuracy of the model is 90.39%, when considering 1-second frames (frame-level), and 96.13%, when considering audio-level classification (most of the audios have a duration of 10 seconds). Future work in this direction will include on-field testing and distance-to-decibel analyses to understand whether a misclassification is due to an imperfection of the model or to the fact that the alert bell has a low intensity and needs to be maintained.

References

[1] RAILS Project, "Deliverable D1.1: Definition of a reference taxonomy of AI in railways", August 2020, [Online] https://rails-project.eu/downloads/deliverables. Revised, March 2021. DOI: 10.13140/RG.2.2.24887.75681
[2] RAILS Project, "Deliverable D1.2: Summary of existing relevant projects and state-of-the-art of AI application in railways", March 2021. [Online] https://rails-project.eu/downloads/deliverables DOI: 10.13140/RG.2.2.11353.03686
[3] 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)
[4] RAILS Project, "Deliverable D1.3: Application Areas", September 2021, [Online] https://rails-project.eu/downloads/deliverables. DOI: 10.13140/RG.2.2.15604.07049
[5] RAILS Project, "Deliverable D2.1: WP2 Report on case studies and analysis of transferability from other sectors" (Submitted for internal review, October 2021)
[6] RAILS Project, "Deliverable D3.1: WP3 Report on case studies and analysis of transferability from other sectors" (In preparation)

4. Research products:

RAILS project deliverables (available online: https://rails-project.eu and ResearchGate):

- *Nikola Bešinović, Ruifan Tang, 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", published, March 2021. - NOT indexed in Scopus or ISI Web of Science*

- *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", published, September 2021. - NOT indexed in Scopus or ISI Web of Science*

Scientific papers:

- *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, IEEE T-ITS, submitted, 2021.*
- *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, IEEE T-ITS, submitted, 2021.*
- *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, TR_C, submitted, 2021.*

5. Conferences and seminars attended

- *IEEE Rising Stars Global 2021, Virtual Event, 2-4 January 2021.*
- *INFORMS Annual Meeting 2021, Anaheim (California), 24-27 October 2021.*
  I attended virtually and discussed a presentation entitled "Dealing With Limited Data: Enabling AI In Railways By Transfer Learning" (oral presentation).

6. Activity abroad:

7. Tutorship