UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DOTTORATO DI RICERCA / PhD PROGRAM IN
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Activities and Publications Report

PhD Student: Lorenzo De Donato

Student DR number: DR995134

PhD Cycle: XXXVI
PhD Cycle Chairman: Prof. Stefano Russo

PhD program student's start date: 01/11/2020
PhD program student's end date: 31/10/2023

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General information

Lorenzo De Donato received in year 2020 the Master Science degree in Computer Engineering from the University of Napoli Federico II. He attended a curriculum in computer engineering within the PhD program in Information Technology and Electrical Engineering. He received a grant from Consorzio Interuniversitario Nazionale per l'Informatica (CINI), partially on the Horizon 2020 Shift2Rail project "RAILS - Roadmaps for AI integration in the rail sector", G.A. n.881782.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Digital Forensics' methods, practices and tools	Ad hoc course	3	Dr. Giovanni Cozzolino	ITEE
1st	Stochastic Modelling	External course	6	Prof. Massimiliano Giorgio, University of Naples Federico II	Scuola Superiore Meridionale, MERC PhD Programme
1st	Scientific Programming and Visualization with Python	Ad hoc course	2	Prof. Alessio Botta	ITEE
1st	Cambridge Assessment English: C1 Advanced (CAE)	External course	6	Dr. Janet Parker, Centro Linguistico di Ateneo	Centro Linguistico di Ateneo
1st	Neural networks and deep learning	MSc course	6	Prof. Roberto Prevete	University of Naples Federico II
2nd	Impreditorialità Accademica	Ad hoc course	4	Prof. Pierluigi Rippa, University of Naples Federico II	ITEE
2nd	Neural Networks and Deep Learning	External course	10	Prof. Giorgio Buttazzo, Scuola Superiore Sant'Anna	Scuola Superiore Sant'Anna
3rd	Using Deep Learning properly	Ad hoc course	4	Dr. Andrea Apicella	ITEE

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
	N/A				

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	AI4NETS - AI/ML for data communication Networks	0.6	Dr. Pedro Casas	Austrian Institute of Technology	Politecnico di Milano jointly with Fondazione Politecnico di Milano
1st	"#andràtuttobene: Images, Texts, Emojis & Geodata in a Sentiment Analysis Pipeline	0.3	Dr. Serena Pelosi	University of Salerno	University of Naples Federico II
1st	Patent Searching Best Practices with IEEE Xplore	0.2	Dr. Eszter Lukacs	IEEE	ITEE, IEEE
1st	How to Get Published with IEEE	0.3	Dr. Paul Henriques	IEEE	ITEE, IEEE
1st	Artificial Intelligence Between Research and Industry	0.3	Marco Cristani, Rita Cucchiara, Alessio Del Bue, Olivia Gambelin, Vittorio Murino, Stefan Raue	Respectively: University of Verona; University of Modena and Reggio Emilia; Italian Institute of Technology; Ethical AI; University of Verona and Huawei; Arceptive	The Consulate 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, Scotland
1st	Cybercrime and e-evidence: the criminal justice response	0.2	Eng. Matteo Lucchetti	Cybercrime Programme Office of the Council of Europe	University of Naples Federico II
1st	Machine Learning: causality lost in translation	0.3	Prof. Edwin A. Valentijn	Rijksuniversiteit Groningen, Netherlands	University of Naples Federico II
1st	EU's AI Policy & Regulation: How can SMEs and Start-Ups test the trustworthiness of the AI applications	0.2	Olga Hamama	V29 Legal	Grassroots Arts
1st	MONDAIS: AI for safety-critical systems	0.3	Marc Baumgartner,	Respectively: IFATCA;	datascience.aero

			Marta Llobet, Darío Martínez	EUROCONTROL; DataBeacon	
1st	Pie & AI: Edinburgh - Breaking into AI	0.2	Koorosh Aslansefat	University of Hull, UK	DeepLearning.AI
1st	Modelling the Complexity of Multiagent Activity for Human-AI Interaction using Dynamical Primitives	0.3	Prof. Michael Richardson	Macquarie University, Australia	Scuola Superiore Meridionale
1st	Risk assessment in real life: experiences from the railway domain	0.3	Emilia Di Martino, Diego Gerbasio, Claudio Mazzariello, Aniello Paolillo	Hitachi Rail STS	University of Naples Federico II
1st	Aerospace Cyber-Physical Systems: Towards Trusted Autonomous Air and Space Operations	0.2	Prof. Roberto Sabatini	RMIT University – School of Engineering	IEEE SMC Society Italy Chapter of the Italian Section jointly with IEEE ASP AESS
1st	On the synthesis and crowdsourcing of control policies for autonomous agents from data	0.2	Prof. Giovanni Russo	University of Salerno	Scuola Superiore Meridionale
1st	L'esposizione ai campi elettromagnetici generati dal sistema 5G - Metodologie scalari e vettoriali di misura dell'esposizione e tecniche di estrapolazione	0.8	Dr. Sara Adda, Dr. Daniele Franci, Eng. Settimio Pavoncello	1° lecturer: Agenzia Regionale per la Protezione Ambientale del Piemonte. 2° and 3° lecturers: Agenzia Regionale per la Protezione Ambientale del Lazio	ITEE
1st	How to Publish Open Access with IEEE to Increase the Exposure and Impact of Your Research	0.3	Dr. Saifur Rahman, Eszter Lukács, Judy Brady	1° lecturer: Virginia Polytechnic Institute and State University, USA. 2° and 3° lecturers: IEEE	IEEE
1st	Privacy Preserving AI	0.2	Andrew Trask	University of Oxford	Massachusetts Institute of Technology, USA
1st	Efficient Computing for Deep Learning	0.2	Vivienne Sze	Massachusetts Institute of Technology	Massachusetts Institute of Technology, USA

2nd	Intelligent Monitoring and Control of Interconnected Cyber-Physical Systems	0.2	Prof. Marios Polycarpou	University of Cyprus	Artificial Intelligence Doctoral Academy (AIDA)
2nd	GDPR basics for computer scientists	0.3	Dr. Rigo Wenning	European Research Consortium for Informatics and Mathematics	ITEE
2nd	Self-awareness for autonomous systems	0.2	Prof. Bernhard Rinner	University of Klagenfurt, Austriac	AIDA
2nd	The learning landscape in deep neural networks and its exploitation by learning algorithms	0.2	Prof. Riccardo Zecchina	Bocconi University	University of Naples Federico II
2nd	The role of standards for the future of AI	0.2	Prof. Dr. Simon Burton, Mr. Karsten Roscher	Fraunhofer Institute for Cognitive Systems IKS	Fraunhofer Institute for Cognitive Systems IKS
2nd	Towards Trustworthy AI - Integrating Reasoning and Learning	0.2	Prof. Fredrik Heintz	Linköping University, Sweden	AIDA
2nd	Who pays the bill when an AI-system causes damage?	0.2	Dr. Jan De Bruyne	KU Leuven Centre for IT & IP Law (CiTiP), Belgium, and Universiteit Leiden, Netherlands	ai4media.eu
2nd	Artificial visual intelligence: Perceptual commonsense for human-centred cognitive technologies	0.3	Prof. Mehul Bhatt	Örebro University, Sweden	University of Plymouth, UK
2nd	Potential and challenges of next generation railway signaling systems: Moving Block and Virtual Coupling	0.2	Eng. Joelle Aoun	Delft University of Technology, Netherlands	University of Naples Federico II
2nd	Towards a Political Philosophy of AI	0.4	Prof. Mark Coeckelbergh	University of Wien, Austria	University of Naples Federico II
2nd	Safety First for Autonomous Vehicles: Where Do We Stand? What is Missing?	0.3	Dr. Michael Paulweber, Jyotika Athavale, Qidong Zhao, Prof. Dr. Simon Burton	Respectively: AVL List GesmbH; NVIDIA; CATARC ADC; Fraunhofer IKS	IEEE Standards Association

2nd	Low-code AI: Making AI Accessible to Everyone	0.2	Julia Hoerner	MathWorks	MathWorks	
2nd	Using MATLAB with Python	0.2	Heather Gorr, Yann Debray	MathWorks	MathWorks	
2nd	Continuous Integration with MATLAB and GitHub Actions	0.2	Adam Sifounakis	MathWorks	MathWorks	
2nd	Mind the Gaps: Trustworthy AI for Autonomous Vehicles	0.3	Riccardo Mariani, Joan Mas-Albaigès, Daniela Rittmeier	Respectively: NVIDIA; Technology Centre of Catalonia; Capgemini	IEEE Standards Association	
2nd	La sostenibilità del trasporto pubblico locale su ferro: elementi di efficientamento	0.7	Prof. Mario Pagano (organizer)	University of Naples Federico II	University of Naples Federico II	
2nd	AI with Model-Based Design: Virtual Sensor Modeling	0.2	Lucas García	MathWorks	MathWorks	
2nd	Medical Image Analysis and AI Workflows in MATLAB	0.2	Renee Qian	MathWorks	MathWorks	
2nd	Mind The Gaps: Do You Trust AI-Enabled Autonomous Vehicles? – Sessions 2, 3 and 4	1	IEEE SA Workshop	/	IEEE Standards Association	
3rd	Embracing Data Imperfections Via Domain Enriched Visual Task Learning	0.2	Prof. Vishal Monga	Pennsylvania State University, USA	ITEE	
3rd	Algorithm Unrolling: Efficient, Interpretable Deep Learning for Signal and Image Processing	0.2	Prof. Vishal Monga	Pennsylvania State University, USA	ITEE	
3rd	MLOps: Achieving Operational Velocity with Faster Delivery and Collaboration	0.2	Prof. Tarry Singh	CEO Real.AI and University of Texas at Dallas, USA	ITEE	
3rd	Unleashing the Power of LLMs: a Historical perspective on Generative AI	0.2	Prof. Tarry Singh	CEO Real.AI and University of Texas at Dallas, USA	ITEE	

Research activities

Lorenzo De Donato participated in the research on the integration of Artificial Intelligence (AI) in the rail sector. In this context, the principal objective was to investigate and propose methodologies and practical applications concerning the adoption of AI, specifically Deep Learning (DL) applied to video/audio data, in railway safety and maintenance applications.

Conceptual developments included the definition of a "Vision for Intelligent Train Control", high-level guidelines conceived to support the stepwise integration of AI in Autonomous Trains, and the identification of a methodology for the implementation of modular DL systems (leveraging video/audio data) in railway safety and maintenance applications. These activities also involved the investigation AI-aided Digital Twins.

Then, experimental activities were oriented at addressing two case studies: i) vision-based obstacle detection on rail tracks, given its relevance for Autonomous Trains; and ii) railway assets continuous monitoring through audio/video data, with focus on Level Crossings which, being the point of intersection between rail and road, are among the most sensitive railway assets. These activities included the implementation of DL approaches for audio classification, semantic segmentation, object detection, and image anomaly detection, as well as strategies to cope with the data availability problem (including Transfer Learning and the development of virtual railway scenarios in RoadRunner and Unreal Engine).

Other activities included the co-authoring of most RAILS Deliverables.

Tutoring and supplementary teaching activities
N/A

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	23	5.4	32	0
2nd	14	5.7	45	0
3rd	4	0.8	60	0

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
2nd	Linnaeus University (LNU), Växjö, Sweden	Prof. Francesco Flammini, co-supervisor	01/09/2022 – 22/12/2022	*Research on* AI-aided Digital Twins that, afterwards, led to the *joint writing* of two papers: "Towards AI-assisted digital twins for smart railways: preliminary guideline and reference

architecture" and "Integrating AI and DTs: Challenges and Opportunities in Railway Maintenance Application and Beyond" (details are given below).

Lab experiments on the simulation of a virtual railway scenario in RoadRunner to collect synthetic video data simulating a camera mounted on the head of the train. Then, unsupervised deep learning approaches for vision-based anomaly detection on rail tracks were investigated and with the support of LNU's High-Performance Computing Center (HPCC) resources.

Other activities:
I attended the "Big Data Conference 2022" organised by LNU where I also presented a poster titled "Dataset Challenges in Railway Machine Learning Applications: The Case-Studies of Level Crossing Monitoring and On-Track Obstacle Detection". Then, invited by the hosting university, I gave a seminar titled "Roadmaps for AI Integration in the Rail Sector: Current Project Results and Overview of Case-Studies". I contributed to the preparation of a book chapter titled "Artificial Intelligence in Railways: Current Applications, Challenges, and Ongoing Research" (details are given below).

PhD Thesis

In the PhD Thesis, Lorenzo De Donato discusses methodologies and applications for the introduction of Artificial Intelligence (AI), specifically Deep Learning (DL), in railway safety and maintenance applications. The attention was mainly cantered around the combination of DL techniques with cost-effective and non-intrusive sensors (cameras and microphones), as well as on the opportunities that these could introduce in supporting autonomous trains and in the continuous monitoring of safety-critical railway assets.

To move towards fully autonomous trains, one of the main research directions that is catching the attention of the railway panorama concerns the possibly of giving trains the capabilities of taking decisions in autonomy to, e.g., dynamically adapt to changes in the environment. In this context, the detection of entities obstructing the safe run of the trains would be one of the main functionalities. This thesis analyses to what extent DL and cameras could be adopted to detect any kind of obstacles (both specifiable and not specifiable a-priori) on rail tracks.

As for maintenance concerns, there are two main aspects to consider. First, traditional inspection activities are conducted on the field by following a fixed schedule; however, such practices may not allow for the timely detection on failures occurring between consecutive inspections. Second, in case of safety-critical assets, they should be compliant with strict safety standard to be deemed operational; modifying them, e.g., by physically installing new sensors, might lead to expensive and time-consuming re-approval processes. In this context, this Thesis analyses the possibility of adopting cost-effective and non-intrusive sensors, specifically microphones and cameras, to continuously monitor railway assets; the case study is cantered on Level Crossings which, being the point of intersection between rail and road, are among the most sensitive railway assets.

The Thesis, first, introduces a reference taxonomy for AI in railway with the aim of shedding light on the main AI concepts that might be of practical relevance to researchers and, more importantly, practitioners approaching the problem of integrating AI into railway applications for the first time. Then, provides an overview of the current panorama on DL approaches developed in the context of the aforementioned topics, namely: vision-based obstacle detection on rail tracks and railway assets monitoring through audio/video data. Hence, analyses the main factors that are slowing the process of integration of AI/DL in railway safety-critical applications, discussing certifiability concerns and data-related challenges.

Second, the Thesis proposes a "Vision for Intelligent Train Control", representing high-level guidelines for the stepwise adoption of intelligent applications in Autonomous Trains. Then, discusses a methodology for the implementation of modular DL systems (leveraging video/audio data) in railway safety and maintenance applications.

Lastly, the Thesis exemplifies the adoption of such a methodology in the context of two case studies, namely: "vision-based obstacle detection on rail tracks" and "level crossing continuous monitoring through audio/video data". Practical experiments included the implementation of DL approaches for audio classification, semantic segmentation, object detection, and image anomaly detection, together with the adoption of strategies to cope with the data availability problem (including Transfer Learning and the development of two virtual railway scenarios in RoadRunner and Unreal Engine).

Research products

Research results appear in *6* papers published in international journals, *2* contributions to international conferences, *1* book chapter, *1* contribution to national conferences, *2* short papers to international conferences.

List of scientific publications

International journal papers

R. Tang, L. De Donato, N. Bešinović, F. Flammini, R.M.P. Goverde, Z. Lin, R. Liu, T. Tang, V. Vittorini, Z. Wang,
A Literature Review of Artificial Intelligence Applications in Railway Systems,
Transportation Research Part C: Emerging Technologies,
vol. 140, pp. 103679, 2022, DOI: 10.1016/j.trc.2022.103679.

L. De Donato, F. Flammini, S. Marrone, C. Mazzariello, R. Nardone, C. Sansone, V. Vittorini,
A Survey of Deep Learning Applications to Railway Maintenance by Audio-Video Analytics,
IEEE Access,
vol. 10, pp. 65376 - 65400, 2022, DOI: 10.1109/ACCESS.2022.3183102.

N. Bešinović, L. De Donato, F. Flammini, R.M.P Goverde, Z. Lin, R. Liu, S. Marrone, R. Nardone, T. Tang,
V. Vittorini,
Artificial Intelligence in Railway Transport: Taxonomy, Regulations and Applications,
IEEE Transactions on Intelligent Transportation Systems,
vol. 23 (9), pp. 14011-14024, 2022, DOI: 10.1109/TITS.2021.3131637.

L. De Donato, S. Marrone, F. Flammini, C. Sansone, V. Vittorini, R. Nardone, C. Mazzariello, F. Bernaudin,
Intelligent Detection of Warning Bells at Level Crossings through Deep Transfer Learning for Smarter
Railway Maintenance,
Engineering Applications of Artificial Intelligence,
vol. 123, pp. 106405, 2023, DOI: 10.1016/j.engappai.2023.106405.

L. De Donato, R. Dirnfeld, A. Somma, A. De Benedictis, F. Flammini, S. Marrone, M. Saman Azari, V. Vittorini,
Towards AI-assisted digital twins for smart railways: preliminary guideline and reference architecture,
Journal of Reliable Intelligent Environments,
vol. 9, pp. 303–317, 2023, DOI: 10.1007/s40860-023-00208-6.

R. Dirnfeld Túrocy, L. De Donato, A. Somma, M. Saman Azari, S. Marrone, F. Flammini, V. Vittorini,
Integrating AI and DTs: Challenges and Opportunities in Railway Maintenance Application and Beyond,
SIMULATION, Accepted, 2023.

International conference papers

F. Flammini, L. De Donato, A. Fantechi, V. Vittorini,
A Vision of Intelligent Train Control,
International Conference on Reliability, Safety, and Security of Railway Systems (RSSRail 2022),
Paris, France, Jun. 2022, pp. 192-208, Springer, DOI: 10.1007/978-3-031-05814-1_14.

R. Dirnfeld, L. De Donato, F. Flammini, M. Saman Azari, V. Vittorini,
Railway Digital Twins and Artificial Intelligence: Challenges and Design Guidelines,
European Dependable Computing Conference (EDCC). Dependable Computing - EDCC 2022 Workshops,
Zaragoza, Spain, Sept. 2022, pp. 102-113, Springer, DOI: 10.1007/978-3-031-16245-9_8.

Book chapters

L. De Donato, R. Tang, N. Bešinović, F. Flammini, R.M.P. Goverde, Z. Lin, R. Liu, S. Marrone, E. Napoletano,
R. Nardone, S. Santini, V. Vittorini,
Artificial intelligence in railways: current applications, challenges, and ongoing research,
In H. Dia (Ed.), Handbook on Artificial Intelligence and Transport. Edward Elgar Publishing, October 2023.

National conference papers

L. De Donato, A. Ferraro, A. Galli, M. Gravina, S. Marrone, V. Moscato, G. Sperlì, V. Vittorini, C. Sansone,
Advanced AI-based approaches in Industry 4.0 of the University of Naples Federico II node of the CINI-AIIS Lab,
3rd CINI National Lab AIIS Conference on Artificial Intelligence (Ital-IA 2023),
Pisa, Italy, May 2023, pp. 1-6, CEUR Workshop Proceedings.

Short papers at international conferences

L. De Donato, F. Flammini, S. Marrone, R. Nardone, V. Vittorini,
Trustworthy AI for safe autonomy of smart railways: directions and lessons learnt from other sectors,
World Congress on Railway Research (WCRR 2022),
Birmingham, United Kingdom, June 2022. https://www.rssb.co.uk/spark/sparkitem/pb029335

L. De Donato, F. Flammini, S. Marrone, R. Nardone, V. Vittorini,
Recommendations and Roadmaps Towards Intelligent Railways,
10th Transport Research Arena (TRA 2024),
Dublin, Ireland, Apr. 2024 (Paper Submitted).
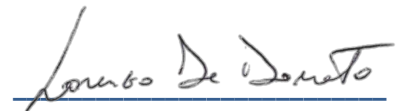
Patents and/or spin offs
N/A

Awards and Prizes
N/A

Date _____20/10/2023_____

PhD student signature _____

Supervisor signature _____