

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

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

Activities and Publications Report

PhD Student: Giovanni Maria Capuano

Student DR number: DR996620

PhD Cycle: XXXVIII

PhD Chairman: Prof. Stefano Russo

PhD program student's start date: 01/11/2022

PhD program student's end date: 31/10/2025

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PhD scholarship funding entity:

Ministero dell'Università e della Ricerca (MUR) – PNRR, DM 352/2022 “Dottorati innovativi” (NextGenerationEU); partner company: Techno System Developments s.r.l., Pozzuoli (NA).

General information

Giovanni Maria Capuano received in year 2022 the Master Science degree in Electronic Engineering from the University of Napoli Federico II. Within the PhD program in Information Technology and Electrical Engineering, he attended a curriculum in Electronics Engineering. He received a scholarship funded by the Italian Ministry of University and Research (MUR, NextGenerationEU) under "PNRR – D.M. 352/2022 - Misura: I.3.3 Dottorati innovativi", with Techno System Developments s.r.l. (Pozzuoli, NA) as industrial partner.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organizer(s)
1 st	Using Deep Learning Properly	Ad hoc course	4	Prof. Andrea Apicella	ITEE
1 st	How to Boost Your PhD	Ad hoc course	4	Prof. Antigone Marino	Polytechnic School
1 st	Statistical data analysis for science and engineering research	Ad hoc course	4	Prof. Roberto Pietrantuono	ITEE
1 st	I Pilastrini della Trasformazione Digitale	Ad hoc course	3	Prof. Francesco Tortorelli, AgID	ITEE
1 st	Scienza Moderna e Disciplina Giuridica dell'Intelligenza Artificiale	Ad hoc course	6	Prof. Lucio Franzese	ITEE
1 st	Visione Per Sistemi Robotici	MSc course	9	Prof. Davide Cozzolino	DIETI
2 nd	Numerical Methods For Thermal Analysis, Modeling, And simulation: Application to Electronic Devices And systems	Ad hoc course	4	Prof. Antonio Pio Catalano	ITEE
2 nd	Industrial Embedded Systems Design with the ARM Architecture	Ad hoc course	4	Prof. Mario Barbareschi	ITEE
2 nd	Machine Learning for Science and Engineering Research	Ad hoc course	5	Prof. Anna Corazza	ITEE
3 rd	Design methodologies for digital circuits and systems oriented to FPGA	Ad hoc course	2.4	Prof. Gennaro Di Meo	ITEE
3 rd	Innovation and Entrepreneurship	Ad hoc course	3	Prof. Pierluigi Rippa	ITEE

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organizer(s)
1 st	Quantum Complexity	0.2	Prof. Alioscia Hamma	University of Napoli Federico II, Department of Physics	Scuola Superiore Meridionale
1 st	Data mining the output of quantum simulators - from critical behavior to algorithmic complexity	0,2	Dr. Oliver Minazzoli	Observatory of Côte d'Azur in Nice – France	Scuola Superiore Meridionale
1 st	Anomaly Detection using Image Processing and Deep Learning	0,2	-	MathWorks	University of Napoli Federico II
1 st	From Cyber Situational Awareness to Adaptive Cyber Defense: Leveling the Cyber Playing Field	0,4	Prof. Massimiliano Albanese	George Mason University - USA	Prof. Marcello Caleffi, (DIETI)
1 st	Game Theory for Information Engineering	0,6	Prof. Leonardo Badia	University of Padua - Italy	Prof. Marcello Caleffi, DIETI - Unina
1 st	Malware Analysis	0,4	Dr. Gaetano Pellegrino	Infoblox	Prof. Piero Bonatti, University of Napoli Federico II
1 st	Entangled Relativity	0,2	Dr. Olivier Minazzoli	Observatory of Côte d'Azur in Nice – France	Scuola Superiore Meridionale
1 st	Is control a solved problem for aerial robotics research?	0,2	Prof Antonio Franchi	University of Twente, Netherlands	Prof. Fabio Ruggiero (DIETI)
1 st	Industry 4.0 Fundamentals in Bosch Applications	2	Eng. Bruni Martino	Bosch Italia	Politecnico di Bari
1 st	Embracing Data Imperfection Via Domain Enriched Visual Task Learning	0,2	Prof Vishal Monga	Pennsylvania State University, USA	Prof. Antonio De Maio (DIETI)
1 st	Algorithm Unrolling: Efficient, Interpretable Deep Learning for Signal and Image Processing	0,2	Prof Vishal Monga	Pennsylvania State University, USA	Prof. Antonio De Maio (DIETI)
1 st	Non Destructive Testing in Aeronautics	0,2	Cap. Giovanni Gravina		Prof. Carlo Forestiere, Unina
1 st	AMD Xilinx Versal for Space and its Ecosystem	0,2	Dr. Ken O'Neill	AMD	Avnet Silica
1 st	Enhancing qubit readout with Bayesian Learning	0,2	Dr. Nicola Lo Gullo	University of Calabria	University of Napoli Federico II,

Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXVIII Cycle

PhD candidate: Giovanni Maria Capuano

					Department of Physics
1 st	How to Publish Under the CARE-CRUI Open Access Agreement with IEEE	0,3	Dr. Nino Grizzuti, Eszter Lukacs, Stefano Bianco	CRUI-CARE, IEEE, INFN and University of Naples Federico II	CARE-CRUI and IEEE
1 st	Unleashing the Power of LLMs: A Historical Perspective on Generative AI	0,2	Prof. Tarry Singh	CEO Real.AI & University of Texas at Dallas - USA	Prof. Antonio De Maio, DIETI - Unina
1 st	MLOps: Achieving Operational Velocity with Faster Delivery and Collaboration	0,2	Prof. Tarry Singh	CEO Real.AI & University of Texas at Dallas - USA	Prof. Carlo Sansone and Dr. Stefano Marrone, DIETI - Unina
1 st	Analysis and Control of Functional Brain Networks	0,2	Prof. Fabio Pasqualetti	University of California, Irvine	Prof. Simone Mancini/ Giacomo Ascione /Francesco Bajardi, DIETI, Unina
1 st	Artificial Intelligence for Defence Seabed-to Space Situational Awareness	0,2	Dr. Paolo Braca	NATO Science and Technology Organization	Prof. Antonio De Maio, DIETI - Unina
1 st	Symbiotic Control of Wearable Soft Suits for human motion assistance and augmentation	0,4	Prof. Lorenzo Masia	Institut für Technische Informatik (ZITI) Heidelberg University, Germany	Prof Fanny Ficuciello (DIETI)
1 st	AI, Robots and Society: Challenge and Opportunities for Social Innovation	0,2	Dr. Amit Kumar Pandey	President Socients AI and Robotics, France Co-Founder Global Institute for Robotics and AI Co-Founder Global Robotics, Arts, and Science Synergie	Prof. Bruno Siciliano, DIETI, Unina
1 st	Cos'è l'Intelligenza Artificiale	0,2	Prof. Giuseppe Trautteur	University of Napoli Federico II	University of Napoli Federico II, Department of Physics
1 st	Exploring Advanced Aerial Robotics: A journey into	0,2	Eng. Eugenio Cuniato	Autonomous System Lab - ETH Zürich	Dr. Julien Mellet (DIETI)

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	cutting edge projects and neural control				
1 st	Ricerca e formazione nella società della transizione digitale	1			CINI
1 st	Come Scrivere un Articolo Scientifico?	0,2	Elisa Magistrelli	Springer Nature	Springer Nature
1 st	Come Funzionano le Riviste?	0,2	Elisa Magistrelli	Springer Nature	Springer Nature
2 nd	Economic Fitness: Concepts, Methods and Applications	0,2	Prof. Luciano Pietrantuono	University of Napoli Federico II	Dr. Della Pia, Dr. Salzano, Dr. Ascione, Dr. Bajardi
2 nd	Energy Efficient Data Science	0,2	Dr. Carlos Ordonez		Prof. Masciari, DIETI, Unina
2 nd	Robotics meets AI & 5G: il futuro è adesso	0,4	Prof. Bruno Siciliano	University of Napoli Federico II	Prof. Massarotti, Prof. Dardano, Prof. Fulgione, Prof. Montesarchio
2 nd	The Generative Power of Deep Learning: Variational AutoEncoders and Generative	0,2	Prof. Enza Messina	Università di Milano Bicocca	Prof. Di Martino, Università della Campania "Luigi Vanvitelli"
2 nd	Fair Spoke Workshop 2024 – Spoke3: Resilient AI	1,2		FAIR - Future Artificial Intelligence Research	Prof. Carlo Sansone, DIETI
2 nd	Analytics Center Selection of Optimization-based Controllers for Robot Ecology	0,2	Prof. Gennaro Notomista	University of Waterloo, Waterloo, Canada	Prof. Bruno Siciliano, DIETI
2 nd	Exploring the Frontiers of Modern Cryptography	0,3	Prof. Antonis Michalas	Tampere University, Finland	Prof. Simon Pietro Romano
2 nd	IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	0,3	Dr. Petar Popovski	Aalborg University, Denmark	IEEE
2 nd	Regolamentazione in tema di intelligenza artificiale alla luce dell'AI act	1	Dr. Elvira Raviele	Dirigente Ufficio di Gabinetto MIMIT	5G Academy/ Prof. Antonia Tulino (DIETI)
2 nd	Intelligenza Artificiale e regole del mercato	0,4	Dr. Massimo Rubino De Ritis	i	5G Academy/ Prof. Antonia Tulino (DIETI)
2 nd	Verso una Gestione Smart della Risorsa Idrica con il supporto della Digital Innovation	0,2	Dr. Enrica Menduni de Rossi		5G Academy/ Prof. Antonia Tulino (DIETI)

2 nd	Using Support Vector Machine for Feature Selection and Outlier Detection	0,2	Prof. Marta Baldomero Naranja	University of Cadiz, Spain	Prof. Maurizio Boccia
2 nd	On the Singe Allocation Hub Location Problems: New Formulation and Solving Methods	0,2	Prof. A.M. Rodriguez-Chia	University of Cadiz, Spain	Prof. Maurizio Boccia
3 rd	The Good, the Bad, and the Ugly in Quantum Computing: Computational Power, Intrinsic Noise, and Transient Faults	0,2	Prof. Paolo Rech	University of Trento, Trento, Italy	Prof. Edo Giusto, DIETI, Unina
3 rd	Trusted Execution Environments for QPUs	0,3	Prof. Jakub Szefer	Northwestern University, Evanston, IL, US	Prof. Edo Giusto, DIETI, Unina

Research activities

Giovanni Maria Capuano participated in the research focused on FPGA hardware acceleration for deep learning-based image processing onboard spacecraft, addressing critical challenges in Earth observation missions. His work centered on enabling near real-time delivery of critical insights through onboard AI processing, reducing dependency on ground stations and communication delays.

His primary contributions include: (1) developing SR-YOLOv5, an enhanced object detection network integrating a super-resolution backbone (SRCNB) to improve small object detection in satellite imagery, achieving superior performance with minimal inference overhead; (2) implementing FPGA-based hardware acceleration using Microchip's PolarFire SoC and CoreVectorBlox accelerator for efficient deployment of deep learning models, conducting comprehensive benchmarking with embedded GPUs.

During his 12-month research period at TSD-Space, he contributed to the EarthNext CubeSat mission, funded by the Italian Space Agency, by deploying AI algorithms on the onboard TSD-Space computer using CoreVectorBlox acceleration. He participated in the ANHEO project, contributing to the development of FPGA hardware designs for AI-powered vision-based autonomous navigation algorithms. Additionally, he contributed to the FOPAC project by developing AI-based multiple image super-resolution and jitter detection algorithms for an active motion control system of electro-optical payload focal planes, employing pixel-shifting acquisition modes and attitude stabilization through jitter contribution inference.

During his ESA ESTEC visiting period, he conducted research on edge AI applications, investigating multigigabit COTS standard interfaces, focusing on Ethernet-based protocols, for high-throughput, low-latency data transfer in time-sensitive applications. His research produced seven conference publications at IAC23, SPAICE, IAC24, 4S, AIAA SciTech, PRIME, and IAC25, with additional journal submissions including Acta Astronautica and CAES Space Journal.

Tutoring and supplementary teaching activities

Giovanni Maria Capuano established a dedicated laboratory set-up at TSD-Space to support the validation of AI models on FPGA platforms. The activity involved the integration and configuration of PolarFire SoC Video Kit and Kria K26 development boards, as well as the preparation of dedicated software environments for AI model compilation and deployment on these devices.

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 st	30	8,7	35	0
2 nd	13	5,3	42	0
3 rd	5,4	0,5	60	2

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
1 st	Techno System Developments S.r.l.	Dr. Mariano Severi, Senior Digital Hardware Design Engineer	5	Research on model-based stereo vision techniques, feasibility studies for pixel-shifting imaging solutions, operational scenario analysis for innovative imaging technologies, commercial piezoelectric nano-positioners, and piezo-actuated Focal Plane Array concept of operations. State-of-the-art analysis of hardware accelerators for embedded AI applications. Study of FPGA-based hardware platforms enabling AI inference in space environments. Analysis of development tools from major FPGA vendors (AMD Xilinx, Microchip) and proprietary IP cores for AI application deployment. Technical analysis of Forward Motion Compensation maneuvers for improving satellite image quality in terms of signal-to-noise ratio and Modulation Transfer Function. Technical contributions to IOS Arm Cameras proposal for In-Orbit Servicing stereoscopic camera development, TSD-Space's EarthNext mission progress report, and Italian Space Agency (ASI) proposal "Tecnologie Abilitanti Robotiche e di Intelligenza Artificiale," defining hardware architecture for onboard AI processing.

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				Lab experiments on AI model deployment workflows using Xilinx Kria KV260 Vision AI Starter Kit (Vitis-AI tools) and Microchip PolarFire FPGA/SoC platforms (VectorBlox SDK), utilizing Deep Learning Processing Unit (DPU) and VectorBlox accelerators. Joint scientific paper preparation: "Super Resolution CNN for a Quincunx Sampling-based Panchromatic Earth Observation Imager for Nanosatellites," presented at International Astronautical Congress 2023.
2 nd	Techno System Developments S.r.l.	Dr. Mariano Severi, Senior Digital Hardware Design Engineer	7	Research on Payload and Platform Data System breadboard design for ASI's EarthNext Earth observation mission, including technical contributions to hardware architecture. Hardware design support for ANHEO unit, an autonomous onboard computer for spacecraft navigation via deep learning algorithms. Analysis of raw data processing techniques with reference to Sentinel-2 mission operational procedures. Study of onboard pixel equalization techniques for satellite image compression optimization. Investigation of ground processing chain methodologies for generating user-deliverable products from optical payload RAW data. Comprehensive study of CCSDS standard and technical contribution to CCSDS packet structure definition for IRIDE VHR mission. Development of In-Flight Verification Plan and In-Flight Maintenance documentation for IRIDE VHR Earth observation mission, addressing operational requirements and maintenance procedures. Lab experiments on porting deep learning algorithms to TSD-Space-developed hardware, utilizing VectorBlox accelerator on Microchip PolarFire SoC to enable onboard image processing for EarthNext spacecraft. Software development activities including implementation of synthetic CCSDS packet generator representative of mission telemetry and software

				tools for RAW data extraction from CCSDS packets for Level-0 ground processor. Porting and optimization of vision-based navigation deep learning algorithms to ANHEO processing unit under development at TSD-Space. Joint scientific paper preparation and presentations: Regular contributions to ASI bimonthly progress reports for funded programs. Abstract presentation "FOcal Plane in-flight Active Motion Control for High-Performance Imaging" at Italian Space Agency workshop "Tecnologie spaziali per le future missioni di ASI." Co-authorship of paper "Preliminary Design and Perspectives of the EartNext Cubesat Mission for Earth Observation from Very Low Earth Orbit," presented at Small Satellite Systems and Services Symposium (4S) 2024. Oral presentation "Electro-Optical Payloads & AI-powered Data Processing Computer for Nanosatellites" at ASI workshop "L'impegno Italiano nel Settore dei CubeSat: Tecnologie e Missioni Future."
3 rd	European Space Agency, European Space Research and Technology Centre, Noordwijk, The Netherlands	Dr. Gianluca Furano, Data Systems Engineer	6	Research on edge AI applications for space systems, investigating multigigabit COTS standard interfaces as alternatives to SpaceFibre for high-throughput, low-latency data transfer in time-sensitive Earth observation applications. Comprehensive analysis of Ethernet-based protocols including standard Ethernet (1000BASE-T). Analysis of CPU-free Ethernet implementations on FPGA pure logic for reduced complexity and power consumption. Investigation of interfacing challenges between COTS AI processing units (embedded GPUs, ASIC accelerators) and traditional space data systems through multigigabit standard interfaces. Lab experiments on FPGA-based Ethernet 10BASE-T MAC

PhD Thesis

In his PhD Thesis, Giovanni Maria Capuano conducted a research project focused on the integration of Artificial Intelligence (AI) within Field-Programmable Gate Array (FPGA) platforms for space applications, with the objective of enhancing the autonomy and real-time decision-making capabilities of future spacecraft. Onboard AI-driven data processing is a cornerstone of next-generation missions, enabling faster responses and reducing dependency on ground communication links. This capability is particularly relevant in in-orbit

operations and deep-space exploration, where communication delays can severely hinder responsiveness, as well as in Earth Observation (EO) missions requiring real-time extraction of insights and alerts to support situational awareness and emergency management.

However, most commercial off-the-shelf edge AI accelerators lack the radiation tolerance required for long-duration or deep-space operations. Space-qualified FPGAs represent a reliable alternative, combining robustness, energy efficiency, and in-flight reconfigurability. Capuano's research investigates FPGA-based acceleration of deep learning models for real-time target detection in optical Earth observation. Specifically, he developed the SR-YOLOv5s architecture, which integrates a convolutional super-resolution backbone designed to enhance the recognition of small maritime targets. The model achieved a mean mAP_{50} of 0.9272 ± 0.0029 and an absolute improvement of +18.26 percentage points in very small object detection compared to the baseline. When implemented on the Microchip PolarFire System-on-Chip with the CoreVectorBlox accelerator, the model reached 18 fps while consuming less than 2 W of power, demonstrating the feasibility of compact and energy-efficient neural pipelines for size-, weight-, and power-constrained platforms such as CubeSats. The radiation-tolerant variant of the PolarFire device further establishes it as a valuable solution for low-power and reliable AI deployment in space.

Beyond model optimization, Capuano designed and validated a complete FPGA-based processing pipeline, spanning from data acquisition to neural inference, within a hardware–software co-design framework. This work contributed to the breadboard-level development of the ANHEO project at TSD-Space, exploring the use of the CoreVectorBlox platform for deploying deep learning models dedicated to vision-based relative navigation. The integration of the CoreVectorBlox within the ANHEO autonomous navigation unit experimentally demonstrated the advantages of FPGA reconfigurability and its value for in-orbit computing. Through bitstream updates, a new IP core was synthesized for the complete management of the relative pose estimation pipeline without resorting to hardware–software model partitioning. The reconfiguration yielded a 3.3× performance improvement and a 50% reduction in energy consumption per frame during the satellite detection task.

Overall, Capuano's work confirms the role of reconfigurable FPGAs as a key enabler of intelligent, adaptive, and resilient spacecraft capable of dynamically reallocating computational resources in response to evolving mission objectives, operational conditions, and algorithmic advancements.

Research products

Research results appear in 2 papers published in international journals, 7 contributions to international conferences.

List of scientific publications

International journal papers

G.M. Capuano, S. Capuozzo, A.G.M. Strollo, N. Petra,
Super-Resolution YOLO Object Detection for Maritime Surveillance with Real-Time FPGA Processing Onboard Spacecraft,
International Journal of Acta Astronautica, Elsevier
vol. 238, Part A, pp. 1291-1310, 2026, DOI: 10.1016/j.actaastro.2025.09.018

T.A. La Marca, M.D. Graziano, M. Grassi, L. Iannascoli, L. Cavicchiolo, A. Capanni, M. Duzzi, G.M. Capuano, V. Fortunato, C. Cardenio, G. Leccese, M. Rinaldi, M. Di Clemente, R. Luciani, R. Natalucci, V. Pulcino,
Mission and system design for the EarthNext Cubesat VLEO mission,
CEAS Space Journal, Springer
vol. 238, pp. 1-17, 2025, DOI: 10.1007/s12567-025-00663-2

International conference papers

G.M. Capuano, A.G.M. Strollo, N. Petra,
Super Resolution CNN for a quincunx sampling-based panchromatic earth observation imager for nanosatellites,
International Astronautical Congress
Baku, Azerbaijan, October 2023, In Proceedings of the International Astronautical Congress, IAC-23,E2,4,5,x79398

G.M. Capuano, S. Capuozzo, A.G.M. Strollo, N. Petra,
FPGA-Based Hardware Acceleration for Real-Time Maritime Surveillance and Monitoring Onboard Spacecraft,
Spaice 2024: Conference on AI in and for Space
European Centre for Space Applications and Telecommunications (ECSAT), Didcot, United Kingdom, October 2024,
In *Proceedings of SPAICE2024: The First Joint European Space Agency/IAA Conference on AI in and for Space* (pp. 156-161)

G.M. Capuano, S. Capuozzo, A.G.M. Strollo, N. Petra,
Super-Resolution-Based Small Object Detection for Real-Time Surveillance and Monitoring: An Onboard Satellite FPGA Implementation,
International Astronautical Congress, Earth Observation Symposium,
Milan, Italy, October 2024, In Proceedings of the International Astronautical Congress, IAC-24-B1.IP.92.X89480

G. M. Capuano, V. Capuano, G. Napolano, R. Opromolla, M. Severi, A. G. M. Strollo, N. Petra, G. Cuciniello, E. Zaccagnino & G. Varacalli
FPGA Hardware Acceleration for Deep Learning-Based Satellite Relative Pose Estimation,
American Institute of Aeronautics and Astronautics SciTech Forum on aerospace research, development, and technology,
Orlando, USA, January 2025, In Proceedings of the AIAA SCITECH 2025 Forum (p. 2715)

G. Leccese, S. Natalucci, L. Iannascoli, M. Melozzi, A. Turella, E. Piersanti, M. Duzzi, F. Trezzolani, G. M. Capuano, T. A. La Marca, M. D. Graziano, M. Grassi, V. Fortunato, P. De Marchi & C. Cardenio,
Preliminary design and perspectives of the EarthNext CubeSat mission for Earth observation from very-low-Earth orbit,
Small Satellites Systems and Services Symposium (4s 2024)
Palma de Mallorca, Spain, May 2024, Vol. 13546, pp. 1264-1279, SPIE

G.M. Capuano, S. Capuozzo, A.G.M. Strollo, N. Petra,
Benefits of FPGAs for Deep Learning Acceleration,
PRIME Conference, 20th International Conference on PhD Research in Microelectronics and Electronics,
Taormina, Italy, September 2025, In Proceedings of the International Astronautical Congress, IAC-24-B1.IP.92.X89480

G. M. Capuano, F. Saggiomo, A. G. M. Strollo, N. Petra, B. Confuorto, E. Zaccagnino & M. Di Clemente,
Enhancing Satellite Imagery through Advanced Focal Plane In-flight Active Motion Control: The FOPAC System Implementation and Results
International Astronautical Congress, Earth Observation Symposium,
Sydney, Australia, October 2025, In Proceedings of the International Astronautical Congress, IAC-25-B1,IPB,17,x96978

Patents and/or spin offs

Awards and Prizes

Date 23/10/2025

PhD student signature



Supervisor signature

