UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

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

Activities and Publications Report

PhD Student: Fabrizio Lo Regio

Student DR number: DR996972

PhD Cycle: XXXVIII
PhD Chairman: Prof. Stefano Russo

PhD program student's start date: 01/01/2023
PhD program student's end date: 31/12/2025

Supervisor: Prof. Leopoldo Angrisani

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PhD scholarship funding entity: PNRR, Partenariato Esteso PE14, RESearch and innovation on future Telecommunications systems and networks (RESTART)

General information

Fabrizio Lo Regio received in 2022 the Master Science degree in Biomedical Engineering from the University of Napoli Federico II. Within the PhD program in Information Technology and Electrical Engineering, he attended a curriculum in Electric and Electronic Measurements. He received a grant from Università Federico II.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organizer(s)
1st	Statistical data analysis for science and engineering research	Ad hoc course	4	Prof. Roberto Pietrantuono	ITEE
1st	Data uncertainty	MSc course	6	Prof. Leopoldo Angrisani	DIETI
1st	Corso di formazione in progettazione europea	External course	1.6	Intellera Consulting S.p.a.	REACT-EU, Ministero dell'Università e della Ricerca
1st	Progettazione degli esperimenti	MSc course	1.6	Prof. Pasquale Arpaia	DIETI
2st	Strategic orientation for stem research & writing	Ad hoc course	5	Prof. Chie Shin Fraser	ITEE
3nd	Quantum Metrology and Sensors	MSc course	6	Prof. Leopoldo Angrisani	DIETI

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organizer(s)
1st	International Ph.D. School "Italo Gorini" 2023	Firenze, Italy	4	04-08/09/2023	Associazione gruppo di misure elettriche ed elettroniche (GMEE)

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organizer(s)
1st	Accurate and Efficient Numerical Modeling Methods for Superconducting Circuit Quantum Information Processing Devices	0.2	Thomas E. Roth	Purdue University - USA	ITEE
1st	Enhancing qubit readout with Bayesian Learning	0.2	Nicola Lo Gullo	University of Calabria	ITEE

1nd	The state of the art of AI and Physics-Based Simulations in drug discovery	0.2	Andrea Beccari	Head of Discovery Platforms Dompé farmaceutici	CQB, University of Napoli Federico II
1nd	How to publish under the CARE-CRUI Open Access Agreement with	0.2	Nino Grizzuti	University of Naples Federico II	University of Naples Federico II
1nd	Unleash the impact of your research with video and graphical abstracts		Tullio Rossi	External	University of Naples Federico II
1nd	The Dynamics of Social Systems With Higherorder Interactions	0.2	Giacomo Ascione	External seminar at the University of	Scuola Superiore Meridionale
1nd	Quantum communication with continuous variables of light	0.2	Cosmo Lupo	External seminar at the University of	Scuola Superiore Meridionale
1nd	Nanoneuro: The power of nanoscience to explore the frontiers of neuroscience	0.2	Aitzol Garcia-Etxarri	Donostia International Physics Center, Spain	ITEE, Carlo Forestiere
1nd	Models of human motor coordination – a critical assessment and some open problems	0.2	Giacomo Ascione	Scuola Superiore Meridionale	Scuola Superiore Meridionale
1nd	Modelling and Understanding Human Behavior and Action Decisions for predictive human-machine systems	0.2	Simone Mancini	Scuola Superiore Meridionale	Scuola Superiore Meridionale
1nd	Analyzing the Impact of Quantum Computing on Future Wireless Networks	0.2	Riccardo Bassoli	External online seminar	IEEE Spectrum
1nd	Flocks, schools, and crowds: Behavioral dynamics of collective motion	0.2	William H. Warren	Scuola Superiore Meridionale	Scuola Superiore Meridionale
1nd	2023 IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering - IEEE MetroXRAINE2023	4.4			Prof. Pasquale Arpaia
1nd	Conference “Scaling-up digital solutions for active and Healthy living: implementing across scientific disciplines,	3.3			Prof. Maria Triassi

	industrial sectors and scenarios" (AHL - Napoli 2023)				
2nd	Quantum Nexus	9	Berardo Ruggiero, Paolo Silvestrini	Associazione Eudora	Fondazione IDIS – Città della Scienza
2nd	IEEE International Instrumentation and Measurement Technology Conference (I2MTC) 2024	7			University of Glagow, IEEE
2nd	Elettronica superconduttiva basata sull'effetto Josephson: giunzioni Josephson, squid e qubit per le tecnologie quantistiche	0.2	Fabio Chiariello	CNR-INFN	IEEE
2nd	2024 IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering - IEEE MetroXRAINE 2024	4.2			IEEE, Saint Albans
2nd	Qiskit Fall Fest 2024	3	Dott. Roberto Schiattarella	UNINA	Università degli studi di Napoli Federico II, QUASAR Group
3rd	Optimisation-based Control of flexible Resources in Sustainable Energy Networks	0.2	Professor Alessandra Parisio	University of Naples Federico II	Prof. Luigi Glielmo
3rd	Stupor Quanti– Le meraviglie della Meccanica Quantistica	0.6	Dr. Antigone Marino	National Research Council (CNR)	University of Naples Federico II
3rd	Sovranità digitale: cos'è e quali sono le principali minacce al cyberspazio nazionale	0.3	Roberto Baldoni	Ambasciata Italiana in USA	Alessandro Cilardo, University of Napoli Federico II
3rd	IX Forum Nazionale delle Misure	2.4		Associazione gruppo di misure elettriche ed elettroniche (GMEE)	Associazione gruppo di misure elettriche ed elettroniche (GMEE)
3rd	2025 12th International Conference on Electrical and Electronics Engineering	2.2			Middle East Technical University, Turkey
3rd	2025 22nd International Conference on Networking, Sensing, and Control (ICNSC)	2.4			University of Oulu, Oulu, Finland
3rd	Calcolo Quantistico: Un Approccio Full-Stack	0.4	Alioscia Hamma	University of Naples Federico II	University of Naples Federico II
3rd	IEEE International Workshop on Metrology for Sustainability	1.0			University of Sannio

Research activities

He participated in the research establishing the discipline of Interaction Engineering dedicated to optimizing smart environments within the emerging Industry 5.0 landscape. Moving beyond qualitative usability studies, his work placed predominant focus on the rigorous development and metrological characterization of advanced Natural Human-Machine Interfaces (NHMI) embedded in Extended Reality (XR) devices, conceptualizing them as sophisticated Human-Edge platforms. A significant portion of this work was devoted to refining wearable communication systems, specifically targeting the optimization of eye-tracking, gesture recognition, and Brain-Computer Interfaces (BCI) to ensure the symbiotic integration of physical actions and digital systems. He was instrumental in defining a novel, standardized methodology compliant with the Guide to the Expression of Uncertainty in Measurement (GUM) to formally assess the precision and reliability of virtual object selection, addressing a critical metrology gap regarding measurement uncertainty and the opacity of commercial hardware specifications. The method was substantiated through extensive experimental campaigns using the Microsoft HoloLens 2, analysing eye-tracking, head-tracking, gesture recognition and Stead-State Visually Evoked Potentials (SSVEP) BCIs.
Expanding into distributed systems, the work conceptualized Metrology-Driven Robotic Sensor Networks, redefining multi-robot fleets as reconfigurable instruments to ensure valid measurement metrics and sustainability. Finally, the research addressed security by validating a client-server architecture based on Quantum Key Distribution; this proof-of-concept demonstrated that quantum encryption could be effectively integrated into critical measurement networks to guarantee data integrity without compromising real-time responsiveness.

Tutoring and supplementary teaching activities

Supplementary teaching activities as lecturer for "Voltmetri digitali" in the bachelor's degree course "Fondamenti di misure" of Professor Mauro D'Arco, BSc in Biomedical Engineering.
Support for bachelor's and master's students for the thesis work development in Biomedical Engineering.

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	17.2	10.2	31	1.6
2nd	5	14.7	41	0.8
3rd	6	9.5	43	0

While there is a slight deviation in the distribution of credits for standard 'Courses', this is fully compensated by an intensive engagement in the 'Seminars' program. This strategic balance was adopted to prioritize specialized workshops and dissemination activities directly relevant to the doctoral project. Consequently, this approach has fostered substantial progress in ***Research activity.*** *Considering the training offer as a whole, the number of hours dedicated to training reaches and exceeds the required number.*

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
3st	University of Oulu, Oulu, Finland	Shuai Li, Associate Professor	26/02/2025 – 05/06/2025	The research activity concerned the optimization-based measurement approaches for mobile robot control. The primary activity focused on the conceptualization of Metrology-Driven Robotic Sensor Networks. Challenging the traditional view of multi-robot fleets as static data carriers, this research redefined the network as a reconfigurable measuring instrument. Just as the thesis work sought to decompose human variability to ensure data integrity, this research utilized optimization-based control to dynamically adapt the fleet's spatial configuration, thereby maximizing the validity of environmental metrics in real-time. Crucially, this framework was broadened to encompass holistic sustainability goals. Moving beyond simple navigational efficiency, the research rigorously assessed the trade-offs between measurement accuracy and the operational footprint of the fleet, demonstrating that a truly "smart" ecosystem must optimize not only the quality of the sensed data but also the energy consumption of the resources employed to acquire it. Concurrently, the activity provided the necessary metrological counterpart by focusing on the human operator as a mobile sensing node. The study formalized the transition of eXtended Reality (XR) Head-Mounted Displays (HMDs) from passive visualization tools to fully fledged measuring systems, introducing the concept of human operator variability. Whether the sensing node is an autonomous robot or a human wearing an XR HMD, the fundamental challenge remains the reliable characterization of a mobile carrier. Together, these activities confirm that objective metrological characterization is the cross-disciplinary prerequisite for integrating any mobile agent, biological or artificial, into the Industry 5.0 measurement chain. Joint scientific paper preparation for "2025 IEEE International Workshop on Metrology for Sustainability" (Benevento, Italy, 4.5 December) and for "2025 22nd International Conference on Networking, Sensing, and Control (ICNSC)", (Oulu, Finland, October 1-3).

PhD Thesis

In the PhD Thesis, Fabrizio Lo Regio focused on the paradigm that shifts toward Industry 5.0, redefining the industrial landscape by placing the human operator at its core, necessitating a symbiotic integration between physical actions and digital systems. Within this framework, eXtended Reality (XR) has evolved from a simple visualization technology into a sophisticated Human-Edge platform where the XR Head-Mounted Display functions as a critical terminal node. This allows Natural Human Machine Interfaces (NHMIs) to interpret innate human behaviors, ranging from gaze and gestures to brain activity, and convert them into digital commands. However, the effective integration of these interfaces into safety-critical industrial and healthcare domains is currently obstructed by a significant Metrology Gap. While future networks promise highly reliable communications, the reliability of the entire chain is compromised at the source if the generation of the data itself is not trustworthy. Current evaluations predominantly rely on qualitative usability studies, which fail to provide the objective guarantees required for operational trustworthiness or to address the opacity of commercial hardware specifications. This gap is characterized by the absence of standardized characterization protocols, the opacity of commercial hardware specifications, and, critically, the lack of rigorous methods to quantify the stochastic impact of human variability on system performance. To bridge this gap, this doctoral thesis establishes the discipline of Interaction Engineering, shifting the paradigm from subjective assessment to rigorous metrological characterization. By treating the NHMI not as a consumer gadget but as a measuring instrument, this thesis proposes a unified framework compliant with Guide to guide to the expression of uncertainty in measurement (GUM). This framework characterizes a wide spectrum of HMIs. The scientific contributions of this work include the development of a standardized modular testbed and the formulation of novel figures of merit to benchmark device capacity independently of hardware specifications. A pivotal innovation of this methodology is the formulation of a comprehensive measurement uncertainty budget that explicitly decomposes performance variability into three distinct categories: instrumental uncertainty, intra-individual variability associated with user repeatability, and inter-individual variability reflecting reproducibility across the user cohort. Experimental validation, conducted using the Microsoft HoloLens 2 as a representative case study, demonstrated the framework's capability to rigorously discriminate performance across diverse interaction paradigms and reveal critical trade-offs between information throughput and spatial precision. The proposed methodology successfully quantified distinct operational profiles, revealing critical trade-offs between performance, while effectively addressing the evaluation of the variability introduced by the users. Ultimately, this work validates the proposed framework as a device-agnostic infrastructure essential for certifying NHMIs as reliable measurement instruments, thereby ensuring the quality of Human-Edge data required for the Industry 5.0 ecosystem.

Research Products

Research results appear in 8 papers published in international journals, 5 contributions to international conferences.

List of scientific publications

International journal papers

L. Angrisani, P. Arpaia, E. De Benedetto, L. Duraccio, F. Lo Regio, A. Tedesco
Wearable Brain-Computer Interfaces based on Steady-State Visually Evoked, Potentials and Augmented Reality: a Review,
IEEE Sensors Journal
23 (15), pp. 16501-16514, 2023, DOI: 10.1109/JSEN.2023.3287983

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L. Angrisani, M. D'arco, E. De Benedetto, L. Duraccio, F. Lo Regio
Broadband Power Line Communication in Railway Traction Lines: A Survey
Energies
16 (17), pp. 6387, 2023, DOI: 10.3390/en16176387

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L. Angrisani, E. De Benedetto, L. Duraccio, F. Lo Regio, R. Ruggiero, A. Tedesco
Infrared Thermography for Real-Time Assessment of the Effectiveness of Scoliosis Braces
Sensors
23 (19), pp. 8037, 2023, DOI: 10.3390/s23198037

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L. Angrisani, M. D'arco, E. De Benedetto, L. Duraccio, F. Lo Regio, A. Tedesco
A Novel Measurement Method for Performance Assessment of Hands-Free, XR-Based Human–Machine Interfaces
IEEE Sensors Journal
24 (19), pp. 31054-31061, 2024, DOI: 10.1109/JSEN.2024.3444472

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A. Procopio, A. Tedesco, F. Lo Regio, G. Cesarelli, L. Donisi, C. Ricciardi, A. Merola, A. Maria Ponsiglione, M. Romano, F. Montefusco, C. Cosentino, F. Amato,
A General Framework for Closed Loop Negative Feedback Multivariable Physiological Control Systems: Existence, Uniqueness, and Stability of Homeostatic Equilibrium Points,
IEEE Access
13, pp. 17630-17651, 2025, DOI: 10.1109/ACCESS.2025.3532846

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L. Angrisani, M. D'arco, E. De Benedetto, L. Duraccio, F. Lo Regio, A. Tedesco
A method for the metrological characterization of eye-and head-tracking interfaces for human–machine interaction through eXtended Reality head-mounted displays
Measurement
243, pp. 116279, 2025, DOI: 10.1016/j.measurement.2024.116279

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L. Angrisani, M. D'arco, E. De Benedetto, L. Duraccio, F. Lo Regio, M. Sansone, A. Tedesco
Performance Measurement of Gesture-Based Human–Machine Interfaces Within eXtended Reality Head-Mounted Displays
MDPI Sensors
25 (9), pp. 2831, 2025, DOI: 10.3390/s25092831

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L. Angrisani, P. Arpaia, E. De Benedetto, M. D'Iorio, L. Duraccio, F. Lo Regio, A. Tedesco
An open Steady-State Visually Evoked Potentials Dataset for Augmented Reality-based Brain-Computer Interfaces
IEEE Sensors Journal
25 (20), pp. 38957-38965, 2025, DOI: 10.1109/JSEN.2025.3605813

International conference papers

L. Angrisani, P. Arpaia, E. De Benedetto, L. Duraccio, F. Lo Regio, A. Tedesco
Expanding the Frontiers of Wearable Brain-Computer Interfaces Combining Augmented Reality and Visually Evoked Potentials,
2023 IEEE INTERNATIONAL CONFERENCE ON Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering,
Milan, Italy, 25-27 October 2023, pp. 58-62, DOI: 10.1109/MetroXRAINE58569.2023.10405702

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F. Lo Regio, L. Angrisani, M. D'arco, E. De Benedetto, L. Duraccio, A. Tedesco
Experimental procedure for metrological characterization of AR-based eye-tracking interfaces
2024 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)
Glasgow, United Kingdom, May 2024, pp. 1-6, DOI: 10.1109/I2MTC60896.2024.10561006.

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L. Angrisani, E. De Benedetto, L. Duraccio, F. Lo Regio, M. Sansone, A. Tedesco
Exploring Variability in Human-Machine Interaction through Gesture Recognition based on Hand-Tracking within XR
2024 IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE)
St Albans, United Kingdom, October 2024, pp. 816-820, DOI: 10.1109/MetroXRAINE62247.2024.10796138.

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L. Angrisani, P. Arpaia, M. D'Arco, E. De Benedetto, L. Duraccio, F. Lo Regio
A Metrological Approach to the Performance Characterization of Eye- and Head-Tracking Interfaces in eXtended Reality
2024 IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE)
St Albans, United Kingdom, 2024, pp. 816-820, DOI: 10.1109/MetroXRAINE62247.2024.10796138.

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F. Lo Regio; M. D'Iorio; L. Angrisani; C. Bruscino; P. Ercolano; M. D'Arco; A. Giuliana; L. Parlato; M. Peluso; G. P. Pepe,
Proof-of-concept of a QKD-secured distributed measurement system,
2025 12th International Conference on Electrical and Electronics Engineering (ICEEE),
Istanbul, Turkey, September 2025, pp. 371-375, DOI: 10.1109/ICEEE67194.2025.11261974.

Awards and Prizes

Sustainable Innovation Award to "Robotics in Sustainability: Opportunities and Challenges for a Holistic Environmental Assessment", received at 2025 IEEE International Workshop on Metrology for Sustainability, Benevento, Italy, 4.5 December.

Date 15/12/2025

PhD student signature 

Supervisor signature