Research Report 2022

Dipartimento di Ingegneria Informatica, Automatica e Gestionale Antonio Ruberti

DIPARTIMENTO DI INGEGNERIA INFORMATICA,
AUTOMATICA E GESTIONALE ANTONIO RUBERTI

DIAG Report 2023

SAPIENZA
UNIVERSITÀ DI ROMA

Dipartimento di Ingegneria Informatica, Automatica e Gestionale Antonio Ruberti

Via Ariosto 25, 00185 Roma

www.diag.uniroma1.it

Dipartimento di Ingegneria informatica, automatica e gestionale
Antonio Ruberti
Sapienza Università di Roma

DIAG Report 2023

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Contents

1 Introduction

The present document is a report about the research and dissemination activities carried out in 2023 at the Department of Computer, Control, and Management Engineering "Antonio Ruberti" (DIAG) of the Sapienza University of Rome.
DIAG (formerly known as DIS - Dipartimento di Informatica e Sistemistica "Antonio Ruberti") was established in 1983 as an evolution of the Istituto di Automatica; in 2001 it was named after Antonio Ruberti, the eminent scholar who founded it. For many years DIAG was distributed over three sites far apart from each other. In May 2007 it moved to the completely renewed premises of Via Ariosto 25, in the center of Rome. In 2011 the department changed its Italian name to the new Dipartimento di Ingegneria informatica, automatica e gestionale "Antonio Ruberti" with the aim of better representing its current expertise and interests.
DIAG is a center for research and education at the undergraduate and graduate levels in computer, control, and management sciences and engineering. Basic research is the main goal of DIAG, with a strong emphasis on interdisciplinary research, on applications that stimulate basic research, and with a specific attention to technology transfer and dissemination of results. Collaborations are maintained with researchers in other university departments, research institutions and companies, in Italy and abroad.
The main educational goal is to prepare students for professional, research and teaching careers in information technologies, automation, and management, either in universities or in industries. The faculty of DIAG in 2023 consists of 40 full professors, 38 associate professors, and 40 assistant professors (researchers). They teach undergraduate and graduate courses in several programs of the two Engineering schools at Sapienza (Facoltà di Ingegneria dell'Informazione, Informatica e Statistica and Facoltà di Ingegneria Civile ed Industriale) and in the Master in Product Design of the School of Architecture (Facoltà di Architettura). Details about teaching activities are not reported in this document; a description may be found at http://www.diag.uniroma1.it, under the section "Teaching".
DIAG offers also four PhD programs, and cooperates with other PhD programs. They are briefly described in Section 2.4 of this report.
Research activities at DIAG are organized in six areas, each composed by one or more research groups.
An overview of each group is reported in Section 3, together with the list of people involved in 2023.

2 General Information

2.1 Location

DIAG is located in the building formerly known as "Scuola Silvio Pellico", in Via Ariosto 25, Rome. DIAG is on the web at http://www.diag.uniroma1.it.

2.2 Facilities

Library

Founded in 1969, the Library of the Department collects books and periodicals related to computer science, control theory, robotics and management engineering. It owns over 12,000 volumes and 450 periodicals. The Library complements its collection with user access to all the key online resources, bibliographic databases, eBooks (accessible both on the library website and in the central online catalog), and scientific content discovery services. In particular, the Library provides access to the main databases in IT and management, i.e., IEEE Library, ACM Library and Derwent Innovation. The Library is open from Monday to Friday 8.30 - 19.30, Saturday 9:00 -13:00. There are two reading rooms available for students, for a total of 87 places. Library facilities are available also to students and faculty members of other departments and universities. In addition to other librarian activities, conferences on specific topics and book presentations are organized. The staff supports also in the insertion and verification of research products of DIAG faculty members in the IRIS database of Sapienza

Research Laboratories

Several research laboratories pertain to DIAG. The following list reports name, location, purpose, and the person in charge for each of them.

ALCOR - Vision, Perception and Learning Robotics Laboratory
Via Ariosto 25 - basement
Research at AlcorLab covers topics of Computer Vision, Pattern Recognition, Deep Learning, Multimedia Analysis and Edge Computing.
Web: http://www.diag.uniroma1.it/alcor
Head: Marco Schaerf

BiBiLab - Bioengineering and Bioinformatics Laboratory
Via Ariosto 25 - basement
The laboratory aims to develop interdisciplinary methodologies by integrating diverse fields, such as signal processing, computer science, systems science, and statistics applied to medical and biological sciences, specifically including: modeling of metabolic systems, information processing from raw molecular biological data to solve interesting biological and medical problems, non-invasive estimation of the electrical activity and functional connectivity of the human brain, development of brain-computer interfaces for assistive and rehabilitation purposes.
Head: Laura Astolfi

Data And Service Integration Laboratory (DASILab)
Via Ariosto 25 - room B213, wing B2
The laboratory is devoted to the development of software research prototypes for service-

based and data-integration systems.
Head: Maurizio Lenzerini

DIAG Robotics Lab
Via Ariosto 25 - basement
The laboratory focuses on the development of advanced planning and control techniques for both industrial and service robots. Experimental validation takes place on fixed-base manipulators, mobile robots, humanoids and flying robots.
Web: http://www.diag.uniroma1.it/labrob
Head: Giuseppe Oriolo

E-learning systems and applications laboratory (ELSA)
Via Andrea Doria 5 (Latina)
In the laboratory, advanced e-learning strategies for robotics and control systems are addressed, developed, implemented and tested through the use of real devices (mobile and articulated robots) available by a web based connection.
Head: Paolo Di Giamberardino

Network Control Laboratory
Via Ariosto 25 - room A215, wing A2
The laboratory is devoted to the design, simulation, and experimental validation of advanced resource management, service management and interoperability management procedures for wireless and wired telecommunication networks as well as in energy distribution networks.
Web: http://diag.uniroma1.it/nclab/
Head: Francesco Delli Priscoli

Research Center of Cyber Intelligence and Information Security (CIS)
Via Ariosto 25 - wing B1
It is a multidisciplinary center developing new knowledge and operational methodologies to gather relevant information from cyber and physical environments and to transform it through intelligence processes in enriched information that can be used to prevent incidents that can harm the society by creating at the same time smarter complex systems.
Web: http://www.cis.uniroma1.it/
Head: Giuseppe Santucci

ROCOCO - COgnitive COoperating RObots Laboratory
Via Ariosto 25 - basement
The laboratory deals with the experimental activities aiming at the implementation of intelligent robots, in several application domains, including agricultural robotics, robots for cultural heritage and service robots. The laboratory is responsible of the SPQR team, which participates in several international robotics competitions.
Web: http://labrococo.diag.uniroma1.it/
Head: Daniele Nardi

Educational Laboratories

DIAG manages also two educational laboratories of the School of Engineering, located outside the DIAG building and used for hands-on teaching and for studying. These are named after Paolo Ercoli, the founder of the Computer science component of the department.

2.3 People

Head of department: Tiziana CATARCI
Administration head: Fabio TUFILLI

Professors

Aris ANAGNOSTOPOULOS
Laura ASTOLFI
Giorgio AUSIELLO (*professor emeritus*)
Alessandro AVENALI
Stefano BATTILOTTI
Luca BENVENUTI
Sara BERNARDINI
Luigia CARLUCCI AIELLO (*ambassador of Sapienza*)
Tiziana CATARCI
Ioannis CHATZIGIANNAKIS
Febo CINCOTTI
Cinzia DARAIO
Giuseppe DE GIACOMO
Alessandro DE LUCA
Francesco DELLI PRISCOLI
Gianni DI PILLO (*professor emeritus*)
Francisco FACCHINEI
Lorenzo FARINA
Antonio FRANCHI
Giorgio GRISETTI
Luca IOCCHI
Alberto ISIDORI (*professor emeritus*)
Domenico LEMBO
Maurizio LENZERINI
Stefano LEONARDI
Pietro LIò
Stefano LUCIDI
Massimo MECELLA
Salvatore MONACO (*professor emeritus*)
Umberto NANNI
Daniele NARDI
Alberto NASTASI
Roberto NAVIGLI
Fabio NONINO
Giuseppe ORIOLO
Laura PALAGI
Chiara PETRIOLI
Veronica PICCIALLI
Leonardo QUERZONI
Pierfrancesco REVERBERI
Riccardo ROSATI
Giuseppe SANTUCCI
Marco SCHAERF
Marco SCIANDRONE
Fabrizio SILVESTRI
Marilena VENDITTELLI
Ivan VISCONTI

Associate professors

Irene AMERINI
Luca BECCHETTI
Roberto BERALDI
Silvia BONOMI
Renato BRUNI
Claudia CALIFANO
Francesco COSTANTINO
Andrea CRISTOFARO
Idiano D'ADAMO
Tiziana D'ALFONSO
Fabrizio D'AMORE
Alberto DE SANTIS
Paolo DI GIAMBERARDINO
Alessandro DI GIORGIO

Giuseppe Antonio DI LUNA
Francesca DI PILLO
Luca FRACCASCIA
Fabio FURINI
Nicola GALESI
Daniela IACOVIELLO
Leonardo LANARI
Riccardo LAZZERETTI
Paolo LIBERATORE
Giampaolo LIUZZI
Andrea MARRELLA
Riccardo MARZANO
Giorgio MATTEUCCI
Christian NAPOLI
Paola PACI
Fabio PATRIZI
Antonio PIETRABISSA
Antonella POGGI
Massimo ROMA
Simone SAGRATELLA
Marco TEMPERINI
Jlenia TOPPI
Andrea VITALETTI

Assistant professors (ricercatori)

Simone AGOSTINELLI
Alessandro ANNARELLI
Pietro ARICO'
Ala ARMAN
Federica BACCINI
Edoardo BARBA
Graziano BLASILLI
Thomas Alessandro CIARFUGLIA
Gianluca CIMA
Silvia COLABIANCHI
Emma COLAMARINO
Simone CONIA
Marco CONSOLE
Chiara CONTI
Anna Livia CROELLA
Daniele Cono D'ELIA
Emanuele DE SANTIS
Simone DI LEO
Valerio DI VIRGILIO
Valerio DOSE
Giulia FISCON
Federico FUSCO
Mirko GIAGNORIO
Alessandro GIUSEPPI
Martina GREGORI
Chiara GROSSO
Simone LENTI
Francesco LEOTTA
Francesco LIBERATI
Mattia MATTIONI
Eugenio OROPALLO
Manuela PETTI
Gabriele PROIETTI MATTIA
Giulio RIGONI
Paolo RUSSO
Saverio SALZO
Federico Maria SCAFOGLIERI
Nicola SCIANCA
Federico SICILIANO
Antonio Maria SUDOSO
Giovanni TRAPPOLINI
Elena UMILI

Post doc (research associates) and research assistant

Giorgio BARNABÒ
Davide BAZZANA
Simone BOESSO
Maria Sofia BUCARELLI
Cesare CAMPAGNANO
Davide CAPOZZI
Massimiliano D'ANGELO
Valeria DE SETA
Luca DI GIAMMARINO
Paolo FERRARI
Marco FERRO
Simone FIORAVANTI
Benedetta GAMBOSI
Giordano LAURENZI
Agnese MACORI
Luca MAIANO
Danilo MENEGATTI
Marta MONACI
Flavia MONTI
Lorenzo PORCARO

Maria Grazia PUXEDDU
Vincenzo RONCA
Valeria RUSCIO
Francesco SAPIO
Olga SOROKOLETOVA
Simone TEGLIA
Andrea TORTORELLI
Luigi VONA
Andrea WRONA

Administration staff

Salvatore BARBIERI
Adriano BENASSI
Antonella CANCELLIERI
Federica CANNELLI
Ugo CINELLI
Sara CIOTTI
Alberta DEL PUNTA
Andrea DORI
Stefano FIORUCCI
Sabrina GIAMPAOLETTI
Domeniko KOLZIU
Domenico MACARI
Giulia OLIVIERI
Marcello PANI
Alessia POLCINO
Roberta PROIETTI SEMPRONI
Francesco SPOGNARDI
Tiziana TONI
Fabio TUFILLI
Fulvio VALENTE
Concetta VELLA
Alessandra VERBENA

2.4 Doctoral programs

DIAG offers the two PhD programs in Automatic Control, Bioengineering and Operations Research and in Engineering in Computer Science, hosts a section of the national doctorate program in Artificial Intelligence, and cooperates with the PhD program in Data Science offered by another department.

Automatic Control, Bioengineering and Operations Research

Coordinator: Giuseppe Oriolo

L'obiettivo formativo del dottorato in Automatica, Bioingegneria e Ricerca Operativa (ABRO) è quello di preparare giovani studiosi a gestire realtà complesse attraverso l'adozione di strumenti modellistici, l'impiego di metodi di analisi di modelli e processi nonché lo sviluppo di tecniche di progetto e implementazione su sistemi reali nei diversi ambiti applicativi.

PhD students

BUDA Christian
MOHEBBAN Shiva
MOSLEMI Mohammad Mahdi
OTTAVIANI Eleonora
SANTOPAOLO Alessandro
SCUPPA Diego
TOMASSINI Riccardo

XXXIX course
CESARONI Edoardo
CICCARELLI Fabio
GERMANO Daniele
PATARINI Francesca
RICCARDI Giulia

XXXV course
DONSANTE Manuel
LAZICH Aldo

XXXVI course
BELVEDERE Tommaso
CALAMITA Alice
CIPRIANO Michele
D'ONOFRIO Federico
MEROLLA Davide
TANTUCCI Andrea

XXXVII course
BRILLI Andrea
COPPOLA Corrado
D'AVINO Arcangelo
MARIOSA Raffaele
MONGIARDINI Elena
PATRIA Daniele
PIERMARINI Christian
PRIORI Gianluca
PUSTINA Pietro
ZUBAIR Muhammad

XXXVIII course
BALDISSERI Federico
D'ORAZIO Francesco
GIANCOLA Francesca
GOVONI Lorenzo
MAIANI Arturo
MENCHETTI Marco
PANNONE Alessandro
QUATTROCIOCCHI Ilaria
RANIERI Andrea
SASSO Valerio
SCARPONI Giulio

Cybersecurity

Coordinator: Leonardo Querzoni

Cybersecurity today represents a rapidly growing research area with important multidisciplinary aspects, ranging from purely technological issues to aspects related to the control of data and information flows in complex socio-technical scenarios such as healthcare, e-government, digital business, finance, logistics and energy. Cybersecurity also offers a promising research field to advance theoretical knowledge in disciplines such as computing, information systems, management, innovation, regulation and strategy. The research topics of interest for the PhD include: system security, software, hardware and network security, cryptography, cyber risk management, data security and privacy, security governance, supply chain security, opsec, economics of cybersecurity, high reliability organizations, disinformation.

PhD students

CIRILLO Lorenzo
COLAGROSSI Tiziano

XXIX course
MAZZINI Pietro

XXXIX course
BONAVENTURA Tania Sari

XXXVI course
BARDHI Enkeleda

XXXVIII course
DI PIETRO Giorgia
MARINI Matteo
PRIAMO Giacomo

Data Science

Coordinator: Stefano Leonardi

The Academic Board of the PhD program in Data Science is coordinated by Stefano LEONARDI. Data Science is an interdisciplinary field of study that has established itself in recent years in order to offer the methodological tools and technologies necessary for the management and analysis of big data and their valorisation in industry, services, and search. The phenomenon of big data has revolutionized countless sectors of economicsocial activity. The phenomenon of big data has also profoundly modified the research methodologies and the development of technological innovation in numerous disciplines and applications. The main objective of this PhD is the realization of interdisciplinary research projects of Data Science that lead to the development of innovative methodologies and technologies based on the use of big data in the following fields of application:

- Advanced digital platforms,
- Management of urban spaces and environmental resources
- Medicine and health
- Economic and Social Analysis.

PhD students

MASCOLO Davide
PALMA Alessio

XXXIX course
BETTI Martina
DI FRANCESCO Andrea Giuseppe
FIANDRINO Stefania

XXXV course
MAIANO Luca
MASTROPIETRO Andrea
OBUKHOV Timur

XXXVI course
ABRATE Carlo
BUCARELLI Maria Sofia
CINUS Federico
D'ACUNTO Gabriele
DENNI Riccardo
GIUSTI Lorenzo
SICILIANO Federico

XXXVII course
BENEDETTI Roberto
CASSARA Giulia
DI GIOVENALE Stefano
FUSO Federica
GEBRETENSAE Yacob Tsegay
LAURENTI Laura
ONORATI Andrea
PEZONE Francesco
SAMPIERI Alessio
SCOFANO Luca
TELYATNIKOV Lev
TESTA Lucia

XXXVIII course
BAIOCCHI Alessandro
CASO Francesco
CECCARONI Riccardo
DE CARLO Gianluca
DEVOTO Alessio
FERILLI Marco
FIORELLINO Simone
GIOIA Matteo
GUERRA Marco
JIMENEZ GUTIERREZ Daniel Mauricio
LENTI Jacopo
PAWLOWSKI Michal
POMARO Angela
RUSSO Matteo
SAURIO Gaetano
VERDINI Francesco

Dottorato nazionale in Intelligenza Artificiale

Coordinator: Maurizio Lenzerini

Il Dottorato Nazionale in Intelligenza Artificiale (Phd-AI.it) riguarda un tema centrale per la trasformazione digitale della società. Ha l'obiettivo di mobilitare la comunità nazionale per un dottorato in AI al più alto livello scientifico, tale da dare impulso alla ricerca e all'innovazione industriale e sociale del paese.
Il PhD-AI.it si attua, con il coordinamento del CNR e dell'Università di Pisa, con l'istituzione di 5 dottorati in AI federati, organizzati da un'università capofila e da un ampio consorzio di università ed enti di ricerca. I dottorati hanno una base comune focalizzata sugli aspetti fondazionali dell'AI e 5 aree di specializzazione:

• Sicurezza e cybersecurity, Sapienza Università di Roma
• Salute e scienze della vita, Università Campus Bio-Medico di Roma
• Agrifood e ambiente, Università di Napoli "Federico II"
• Industria 4.0, Politecnico Torino
• Società, Università di Pisa.

PhD students

XXIX course
ANDRADE NEVES Pedro Jorge
BRIGLIA Maria Rosaria
FILOSA Matteo
GENOVESE Donatella

XXXIX course
CUCONASU Florin
D'ORAZIO Antonio
DE REBOTTI Lorenzo
MANCANELLI Matteo
MELIS TONTI Claudia

XXXVII course
BACCIU Andrea
CAPOZZI Gianluca
CAPPELLINI Guglielmo
MATHEW Jerin George
RAGNO Alessio
SCIRè Alessandro

XXXVIII course
ARGENZIANO Francesco
DELFINO Roberto Maria
PARRETTI Gianmarco

Engineering in Computer Science

Coordinator: Luca Iocchi

Il titolo di Dottore di Ricerca (Ph.D.) rappresenta il più alto livello nella formazione accademica. Il corso di Dottorato in Ingegneria Informatica offerto dall'Università di Roma La Sapienza ha lo scopo di fornire le competenze necessarie allo svolgimento di attività di ricerca altamente specializzata in diversi campi dell'Ingegneria Informatica e termina con la stesura di un lavoro di tesi.
I settori di principale interesse del Dottorato in Ingegneria Informatica sono:
- Architetture, sistemi di elaborazione e reti di calcolatori
- Ingegneria degli algoritmi ed analisi di complessità
- Ingegneria del software
- Intelligenza artificiale e rappresentazione della conoscenza
- Intelligenza artificiale e robotica
- Sistemi informativi
- Basi di dati
- Sistemi distribuiti
- Software orientato ai servizi
- Web e reti sociali
- Cyber security & intelligence
- Computer vision & computer graphics
- Interazione persona-calcolatore
- Sistemi multi-agente e Sistemi multi-robot

PhD students

XXXVI course
ARTUSO Fiorella
BAZZANA Barbara
BENVENUTI Dario
BRANDIZZI Nicolo'
BRUNORI Damiano
CARELLO Maria Patrizia
CONSOLE Francesca
CUOCI Marco
DI GIAMMARINO Luca
DI RETO Emiliano
GRAZHDANKIN Mikhail
KASZUBA Sara
MARCONI Lorenzo
PIMPINI Adriano
SURIANI Vincenzo
VENERUSO Silvestro V.

XXXVII course
ALTAMURA Nicola
ASSAIANTE Cristian
BATOOL Aiza
BOTTURA Nicola
BRIZI Leonardo
CIABATTI Giulia
DE MAGISTRIS Giorgio
FAZZINI Paolo
FICARRA Giovanni
FRATTOLILLO Francesco
GBAHOU Davy Yann
GIACOMINI Emanuele
IEZZI Luca
IZZILLO Alessio
MARIOTTI Eleonora
MILANI Stefano
MONTI Flavia
MORVILLO Alberto
ORLANDO Riccardo
PALMA Alessandro
PAPA Lorenzo
ROSSETTI Simone
SABBELLA Sandeep Reddy
SALEM Omar Ashraf Ahmed Khairy
TRAPASSO Alessandro

XXXVIII course
ACITELLI Giacomo
BONOMO Tommaso
COLLORONE Luca
FANTI Andrea
MANDELLI Lorenzo
MANGANELLI CONFORTI Pietro
MARINACCI Matteo
MOTOI Ionut Marian
ODDI Fabio
PERRELLA Stefano
PUGLISI Adriano
ROSSI Jacopo
SARACENI Leonardo

2.5 Visiting Scientists and Scholars

- Ronen BRAFMAN, Ben-Gurion University, Israel, June 2023 to July 2023.
- Yves LESPéRANCE, York University, August 2023 to September 2023.
- Sebastian SARDINA, RMIT Melbourne, Australia, November 2023 to December 2023.

2.6 Seminars and Workshops

Many scientists are invited to deliver seminars at DIAG. Below we report the list of seminars for the year 2023, in chronological order. We also report the workshops and special scientific events organized at DIAG.

- January 20, 2023, Prof. Ophir Frieder: *Prof. Ophir Frieder's Talk: Computational Intelligence for Health*.
- January 26, 2023, Jan Schwidessen: *An Exact Solver for QUBO Problems using the Mixing Method*.
- February 6, 2023, Prof. Martin Schmidt: *A primer on bilevel optimization under uncertainty*.
- February 8, 2023, CORALLA CICCOLINI: *ORGANIZZAZIONE E GESTIONE DI UN GRUPPO DI LAVORO. Il caso dell'Italia campione del mondo 1982*.
- February 15, 2023, *Industrial Automation: The role of the Automation Engineer*.
- February 17, 2023, Nicola Gatti (Politecnico di Milano): *Recent Advancements in Equilibrium Computation for Adversarial Team Games*.
- February 23, 2023, Willem-Jan van den Heuvel: *Towards Data meshes fueling MLOps*.
- March 7, 2023, prof. Emilia Fridman: *"Using delays for control" by Prof. Emilia Fridman*.
- March 7, 2023, Francesco Ferrante: *Stability analysis of a class of discrete-time discontinuous systems*.
- March 14, 2023, prof. Felix Naumann: *Exploring Change – A New Dimension of Data Analytics*.
- March 15, 2023, Professor Arjan van der Schaft: *Joint IFAC/IEEE CSS Nonlinear Control Systems Webinar*.
- March 20, 2023, Giovanni Farina: *Byzantine fault-tolerant information dissemination protocols in distributed systems*.
- March 20, 2023, Ala Arman: *Seminario pubblico di Ala Arman (Procedura valutativa per n. 1 posti di Ricercatore a tempo determinato tipologia A - PNRR PE11 Spoke 8 SC 09/H1 SSD ING-INF/05) - Lunedì 20/03/2023 ore 10.00, Aula Magna*.
- March 20, 2023, Edoardo Barba: *Seminario pubblico di Edoardo Barba (procedura valutativa per n.3 posti di Ricercatore a tempo determinato tipologia A - SC 09/H1, SSD ING-INF/05)*.
- March 20, 2023, Giovanni Trappolini: *Seminario pubblico di Giovanni Trappolini (Procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05)*.
- March 20, 2023, Gabriele Proietti Mattia: *SEMINARIO PUBBLICO DI GABRIELE PROIETTI MATTIA (PROCEDURA VALUTATIVA PER N.1 POSTO DI RICERCATORE A TEMPO DETERMINATO TIPOLOGIA A - PNRR PE7 SPOKE 9 SC 09/H1 SSD ING-INF/05) - LUNEDI' 20/03/2023 ORE 15.00, AULA MAGNA*.
- March 21, 2023, Nicola Scianca: *Seminario pubblico di Nicola Scianca (procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/G1, SSD ING-INF/04)*.
- March 21, 2023, Simone Agostinelli: *Seminario pubblico di Simone Agostinelli (Procedura valutativa per n.3 posti di Ricercatore a tempo determinato tipologia A - PNRR PE1 Spoke 5 SC 09/H1 SSD ING-INF/05) - Martedì 21/03/2023 ore 10.00, Aula Magna*.
- March 21, 2023, Emma Colamarino: *Seminario pubblico di Emma Colamarino (procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/G2 SSD ING-INF/06) - Martedì 21/03/23 ore 11.00, Aula Magna*.

- March 21, 2023, Federico Fusco:Dr. Federico Fusco: *Seminario pubblico di Federico Fusco (Procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05) - 21/03/23 ore 12.00, Aula Magna*.
- March 21, 2023, Gianluca Cima: *Ontology-based Data Management*.
- March 21, 2023, Martina Gregori: *Seminario pubblico di Martina Gregori*.
- March 21, 2023, Riccardo Marzano: *Seminario pubblico di Riccardo Marzano*.
- March 22, 2023, Prof. Joe Naoum-Sawaya: *Optimization Models for Learning Consumer Preferences*.
- April 20, 2023, *Conferimento del premio per tesi di laurea magistrale in memoria del prof. Camil Demetrescu*.
- May 2, 2023, Gabriele Buondonno: *Wandercraft: Making wheelchair users walk again - Presenting the exoskeleton Atalante*.
- May 2, 2023, Tavola rotonda: *Artificial Intelligence, Robots and Torts: Challenges and Perspectives*.
- May 5, 2023, Nikos Vasilakis: *PaSh: Scaling out Shell Programs, Automatically*.
- May 10, 2023, Emanuele De Santis: *Seminario pubblico di Emanuele De Santis (Procedura selettiva per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/G1 SSD ING-INF/04)*.
- May 11, 2023, Dr. Lorenzo Beretta (Univ. of Copenhagen): *Multi-Swap Local Search for K-means: Dr. Lorenzo Beretta (Univ. of Copenhagen)* .
- May 12, 2023, Tarek R. Besold (Sony AI): *Trustworthy AI*.
- May 15, 2023, Silvio Micali: *Laurea Honoris Causa a Silvio Micali*.
- May 15, 2023, Ramy Rashad: *Seminar: Putting energy and geometry back in robotics*.
- May 18, 2023, Yannis Ioannidis: *Seminario di Yannis Ioannidis (ACM President)*.
- May 22, 2023, Cosimo Della Santina, Alessandro De Luca: *EECI 2023 International Graduate School on Control of Soft and Articulated Elastic Robots*.
- May 23, 2023, Silvia Colabianchi: *Seminario pubblico di Silvia Colabianchi (Procedura selettiva per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/B2 SSD ING-IND/17)*.
- May 25, 2023, Antonella Del Pozzo: *Sharding and Blockchain: on the cross-chain smart contracts*.
- May 26, 2023, Roberto Lattanzi (Garante Privacy), Dott.ssa Valentina Buccarelli (CINI): *Seminars in AI and robotics*.
- June 12, 2023, Luca Becchetti:Luca Becchetti (Sapienza University) and Francesco Pasquale (University Tor Vergata Rome): *PhD course - Spectral graph theory and random walks: connections and applications*.
- June 14, 2023, Antonio Maria Sudoso: *Seminario pubblico di Antonio Maria Sudoso - Procedura selettiva per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 01/A6 SSD MAT/09*.
- June 16, 2023, Yuri Faenza: *Stable matchings in choice function models: algorithms, polyhedra, and an application to school choice*.
- June 28, 2023, Prof. Hassene Seddik: *Intelligent robotic ecosystem: needs and applications related to the activity of the RIFTSI research laboratory*.
- July 3, 2023, Amin Mantrach (Amazon), James Thorne (KAIST): *Corso di dottorato Data Science - AI in the Wild & Knowledge Intensive NLP*.
- July 3, 2023, Amin Mantrach, James Thorne: *Data Science PhD course-AI in the Wild & Knowledge Intensive NLP*.

- July 10, 2023, Elena Umili: *Seminario pubblico di Elena Umili (Procedura valutativa per n.4 posti di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05) - Integrating Linear Temporal Logic with Deep-Learning-Based Applications*.
- July 10, 2023, Federica Baccini: *Seminario pubblico di Federica Baccini (Procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05)*.
- July 10, 2023, Anna Livia Croella: *Seminario pubblico di Anna Livia Croella (Procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 01/A6 SSD MAT/09)*.
- July 11, 2023, Graziano Blasilli: *Seminario pubblico di Graziano Blasilli (Procedura valutativa per n.1 posto di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05)*.
- July 11, 2023, Pietro Liò: *Integrating Graph Representation Learning and Diffusion: Computational Models and Applications in Chemistry and Medicine.*.
- July 11, 2023, Leandro de Souza Rosa: *Seminario pubblico di Leandro de Souza Rosa, Procedura valutativa per n.4 posti di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05 - Towards Robots in Our Daily Lives*.
- July 11, 2023, Federico Scafoglieri: *Seminario pubblico di Federico Scafoglieri (Procedura valutativa per n.4 posti di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05)*.
- July 11, 2023, Simone Conia: *Seminario pubblico di Simone Conia (Procedura valutativa per n.4 posti di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05) - .*
- July 12, 2023, Giulio Rigoni: *Seminario pubblico di Giulio Rigoni (Procedura valutativa per n.4 posti di Ricercatore a tempo determinato tipologia A - SC 09/H1 SSD ING-INF/05)*.
- July 19, 2023, Adela del Río Ortega: *Bringing Science to Process Performance Management*.
- September 25, 2023, Andrea Vitaletti:Vangelis Markakis (University of Athens), Ivan Visconti (University of Salerno), Andrea Vitaletti (Sapienza University of Rome), Philip Lazos (Input Output IOG, United Kingdom): *PhD course Data Science: Crypto and Incentive-based Mechanisms for Blockchain Technology*.
- September 25, 2023, Andrea Vitaletti:Vangelis Markakis (University of Athens), Ivan Visconti (University of Salerno), Andrea Vitaletti (Sapienza University of Rome), Philip Lazos (Input Output IOG, United Kingdom): *Course PhD in Data Science*.
- October 16, 2023, Chiara Grosso: *Seminario pubblico di Chiara Grosso, Procedura valutativa per n.1 posti di Ricercatore a tempo determinato tipologia A - SC 09/B3 SSD ING-IND/35 - Closed-loop, sustainable, inclusive factories and processes*.
- October 17, 2023, Mirko Giagnorio: *SEMINARIO PUBBLICO DI MIRKO GIAGNORIO (PROCEDURA VALUTATIVA PER N.1 POSTI DI RICERCATORE A TEMPO DETERMINATO TIPOLOGIA A - SC 09/B3 SSD ING-IND/35)*.
- October 20, 2023, *I-RIM 3D 2023*.
- October 23, 2023, Maria Sofia Bucarelli, Giulia Cassarà, Eleonora Grassucci: *Diversity & Inclusion seminar - 23 October, 10:00 AM, DIAG@Sapienza*.
- November 7, 2023, Pietro Barbiero: *Interpretable Neural Symbolic AI*.
- November 14, 2023, Paul Duetting, Johannes Bruestle: *Seminar PhD Data Science*.

- November 20, 2023, Leonardo Querzoni: *Securing Complex Systems: a bottom-up approach*.
- November 20, 2023, Laura Astolfi: *Seminario pubblico di Laura Astolfi*.
- November 23, 2023, Prof. Sebastian Sardina: *From Non-deterministic Planning to Agent Planning Programs and Goal Recognition*.
- November 23, 2023, Bernhard von Stengel (London School of Economics): *Seminario Bernhard von Stengel (London School of Economics) - Zero-sum Games and LP Duality* .
- November 24, 2023, Janusz Kacprzyk, Gia Sirbiladze, Bezhan Ghvaberidze: *Fuzzy Modeling Problems of Facility Location/Transportation Planning in Disaster-Stricken Zones*.
- December 7, 2023, Andrea Pieris: *Termination Analysis of Rule-based Ontological Reasoning*.
- December 13, 2023, Prof. Everton J. Silva: *Prof. Everton J. Silva: An Inexact Restoration Direct Multisearch Filter Approach to Constrained Optimization*.
- December 13, 2023, Daniele Cono D'Elia: *Seminario pubblico Daniele Cono D'Elia*.
- December 15, 2023, Giorgio Grisetti: *SLAM turns 35*.
- December 19, 2023, *PhD Welcome@DIAG*.
- December 21, 2023, Alessandro Fantoni: *A machine learning approach for the project of an amorphous silicon optical logic gate based on an Electrically Reconfigurable Metamaterial*.

2.7 Terza missione

Attività di coinvolgimento e interazione con il mondo della scuola

February 16 to February 17, 2023, OpenDIAG ONLIFE Edition 2023
January 1, 2023 to December 31, 2024: Antonella Poggi *G4Greta*
December 18, 2023 to December 20, 2023: *Moduli Orientamento NextGen*
June 5, 2023 to June 7, 2023: *Orientamento Next Generation - Sapienza*
December 20, 2023: *Orientamento presso Istituto di Istruzione Superiore "Via Salvo D'Acquisto 69"*
April 21, 2023 to April 24, 2023: *XII festa di scienza e di filosofia-virtute e canoscenza*

Iniziative di co-produzione di conoscenza

April 5, 2023: *AI Forum*
January 18, 2023 to January 19, 2023: *E se fosse...consapevolezza è libertà*
September 12, 2023 to September 13, 2023: Luca Fraccascia, Carlo Meloni *Hack4Future*

Organizzazione di concerti, spettacoli teatrali, rassegne cinematografiche, eventi sportivi, mostre, esposizioni e altri eventi di pubblica utilità aperti alla comunità

October 20, 2023 to October 22, 2023: *Maker Faire Rome 2023*

Organizzazione di iniziative di valorizzazione, consultazione e condivisione della ricerca

October 20, 2023 to October 22, 2023: *I-RIM 3D 2023*
November 28, 2023: Francesco Costantino *Trasformazione digitale e salute e sicurezza: strumenti di analisi dei rischi nuovi ed emergenti nei contesti lavorativi*
Participation in Maker Faire – The European Edition, where a public demo was conducted by Prof. Pietro Aricò showcasing the project *"Wearable EEG system to decode mental states in operational environments"*, a wearable device designed to measure mental and emotional states through brain signal analysis.

Partecipazione a progetti di sviluppo urbano o valorizzazione del territorio

June 9, 2023: Luca Fraccascia *Speech all'evento "Hacking the City"*

Partecipazione alla formulazione di programmi di pubblico interesse

February 1, 2023 to January 4, 2024: *Comitato di Indirizzo ForumPA*
December 11, 2023: Francesco Costantino, Alessandro De Luca *Orientamento presso Liceo Lucrezio Caro a Roma*
May 24, 2023: *Roma Digital Summit*

Pubblicazioni (cartacee e digitali) dedicate al pubblico non accademico

April 27, 2023: *Evento Deloitte su Governo ed Etica dell'IA*
December 12, 2023: *Intelligenza Artificiale, verso la Strategia italiana. L'impatto dell'AI Act sul nostro Paese tra investimenti e regolamentazione*
July 1, 2023 to July 5, 2023: *Metaverse RenAIssance*
July 9, 2023 to November 30, 2023: *Osservatorio sulla Trasformazione Digitale - Cabina di Regia*

Altre iniziative di carattere istituzionale

December 11, 2023: *AI Act: etica, diritto e informatica a confronto*
April 12, 2023 to April 13, 2023: *Convegno Fondimpresa - Il Lavoro al Centro*
October 14, 2023 to November 24, 2023: Emilio Coppa *Cyber Challenge Boot Camp*
September 6, 2023: *Leadership Forum*
September 13, 2023: *MPW for FUTURE - Rome Future Week*
September 11, 2023 to September 10, 2026: Francesco Delli Priscoli, Alessandro Giuseppi *Startup Automation Intelligence and Control srl*
October 27, 2023 to October 28, 2023: *Stati Generali Sostenibilità Digitale*

2.8 Honours and Awards

- Francesco Fuggitti ICAPS 2023 Best System Demonstration Award Runner–Up, The paper "NL2LTL – A Python Package for Converting Natural Language (NL) Instructions to Linear Temporal Logic (LTL) Formulas", by Francesco Fuggitti and Tathagata Chakraborti, received the Best System Demonstration Award Runner–Up

at the Thirty-third International Conference on Automated Planning and Scheduling (ICAPS), held in July 8-13, 2023, in Prague, Czech Republic.

- Giuseppe De Giacomo , Marco Favorito , Francesco Fuggitti ICAPS 2023 Best Student Paper Award, The paper "Planning for Temporally Extended Goals in Pure-Past Linear Temporal Logic", by Luigi Bonassi, Giuseppe De Giacomo, Marco Favorito, Francesco Fuggitti, Alfonso Emilio Gerevini, and Enrico Scala, received the Best Student Paper Award at the Thirty-third International Conference on Automated Planning and Scheduling (ICAPS), held in July 8-13, 2023, in Prague, Czech Republic.
- Roberto Baldoni , Leonardo Querzoni DEBS 10 Years Time Award, DEBS 10 year time best research paper for "Adaptive online scheduling in storm" from the ACM International Conference on Distributed and Event-based Systems
- Idiano D'Adamo Top 2% Global Scientists in 2022, Idiano is among Top 2% Global Scientists in 2022 provided by Elsevier Data Repository. In particular, the ranking places Idiano in position number 18929, and first two topics of reference are "Energy" and "Environmental Sciences" doi: 10.17632/btchxktzyw.6
- Roberto Navigli ACL 2023 Outstanding Paper Award, ACL 2023 Outstanding Paper Award for the paper "Simone Tedeschi, Johan Bos, Thierry Declerck, Jan Hajic, Daniel Hershcovich, Eduard H. Hovy, Alexander Koller, Simon Krek, Steven Schockaert, Rico Sennrich, Ekaterina Shutova, Roberto Navigli:What's the Meaning of Superhuman Performance in Today's NLU? ACL (1) 2023: 12471-12491"
- Roberto Navigli ACL Fellow, Elected ACL Fellow (https://aclweb.org/aclwiki/ACL_Fellows)
- Mirko Giagnorio SIET Best Doctoral Thesis Award, In recognition of outstanding research contributions by young researchers in Transport and Logistics Economics, and to help disseminate their findings, the Italian Society of Transport Economics and Logistics (SIET) awarded the "SIET Best Doctoral Thesis Award". This award, consisting of €1,000, was granted to the best doctoral thesis defended at an Italian university in 2022 or by April 2023. The winner also received a three-year membership to SIET.The theses were evaluated by a Commission appointed by the Society's Executive Committee. The Commission consisted of five members: the President and the Secretary General of SIET, or their delegates, at least one representative from the past presidents, and one or two members designated by the Executive Committee, including individuals from foreign universities.The award ceremony took place during the XXV SIET Conference "Pandemic, Climate Change, and Energy Crisis: How to Adapt the Transportation Systems?" on June 22nd-23rd, 2023, at the University of Trieste.
- Irene Amerini , Paolo Russo Best paper award SUMAC '23, Best paper award Workshop on analySis, Understanding and proMotion of heritAge Contents (SUMAC '23) at ACM MM 2023.
- Pietro Arico' AIIC Awards, AIIC Awards: Selection by the scientific committee to present the scientific work “MINDTOOTH: EEG wearable system for real-time assessment of a patient's mental and emotional states in clinical settings” to the National Conference organized by the Italian Association of Clinical Engineering (AIIC), Florence, Italy
- Pietro Arico' Maker Faire the European edition, Maker Faire the European edition: Selection by the scientific committee to present product “Wearable EEG system to

decode mental states in operational environments" to the Maker Faire, Rome 2023, Rome, Italy

- SUMAC 2023 Best Paper Award, SUMAC 2023 Best Paper Award - "Why Don't You Speak?: A Smartphone Application to Engage Museum Visitors Through Deepfakes Creation" - Matteo Zaramella, Irene Amerini, Paolo Russo - 5th workshop on analySis, Understanding and proMotion of heritAge Contents at ACMMM 2023.
- Antonio Franchi IEEE Fellowship, Prof. Antonio Franchi has been elevated to the grade of IEEE Fellow (class of 2023). This prestigious honour has been awarded by the IEEE – one of the largest association of technical professionals in the world – and acknowledges Prof. Franchi "contribution to modelling, design, and control for aerial and distributed robotic systems". The elevation takes effect from 1 January 2023 and is officially awarded at the IEEE International Conference on Robotics & Automation in May 2023, in London, UK.Contribution To Aerial Robotic SystemsProfessor Franchi made his most significant contribution to the robotics field with his ground-breaking and extensive work, both at the theoretical and experimental level, on the so-called 'generic' multi-rotors. Before the work of professor Franchi and his team, standard aerial robotic systems were limited to the collinear/coplanar structure, such as quadrotors, using symmetrically inclined blades. Dissatisfied by the shortcomings of these platforms, Prof. Franchi's team pioneered the introduction of many novel designs, such as the fully-actuated, omnidirectional (in every direction), morphing, and the cable-interconnected ones. Prof. Franchi's work opened up a completely new research and application horizon in robotics, and enabled the use of aerial vehicles as fully-fledged robotics platforms, which are able to physically interact and manipulate the surrounding environment with an unprecedented level of accuracy and reliability. Nowadays, these platforms have become mainstream in the research and industrial community.Contribution To Distributed Robotic SystemsMulti-robot systems, also called swarms or distributed systems, can achieve tasks that are impossible for a single robot, such as simultaneous exploration, coverage and monitoring of large areas. Besides that, multi-robot systems are resilient to single point failure. Professor Franchi and his collaborators were among the first to introduce the bilateral teleoperation of multiple distributed mobile robots, which means that a single person can control a group of remotely located mobile robots and receive a force feedback that is informative of the status of the swarm. This work provided the engineering community with modeling and design tools to control systems in a way that ensures stability, despite the presence of communication limitations, such as low bandwidth, delays and packet losses. By introducing this and other novel methods, professor Franchi, together with his collaborators, let swarms achieve collective behaviours, such as information control, patrolling and exploration. These algorithms are now widely used in all applications in which robots are employed in the real world.The IEEE FellowshipEach year, based on a rigorous and collective nomination and evaluation process, the IEEE Board of Directors selects a group of members for elevation to IEEE fellow. The total number of prospective IEEE fellows selected in any year cannot exceed the 0.1% of the total voting membership. The IEEE Fellow is the highest grade of membership of the IEEE and is recognised by the technical and scientific community as a prestigious honour and an important career achievement. To exemplify, only four researchers located in the Netherlands have been elevated IEEE Fellows in 2023.

- Emanuele De Santis Premio Minerva, Macroarea D - PhD Students, IV edition- issued by "Fondazione Roma Sapienza", Prize awarded to the single best PhD student of the entire University (for the Macroarea D - Engineering and Architecture). This edition of the award was reserved for young researchers formerly enrolled in either of the XXXII, XXXIII or XXXIV PhD cycles and is recognized to those whose study activity offered a significant contribution to the scientific progress in its disciplinary area.
- Alessandro Giuseppi Premio Minerva - Best Postdoctoral Researcher (Macroarea D), Premio Minerva, Macroarea D - Postdoctoral Researchers, IV edition- issued by "Fondazione Roma Sapienza"Prize awarded to the single best postodoctoral researcher of the entire University (for the Macroarea D - Engineering and Architecture). This edition of the award was reserved for young researchers formerly enrolled in either of the XXXII, XXXIII or XXXIV PhD cycles and is recognized to those whose study activity offered a significant contribution to the scientific progress in its disciplinary area.
- Simone Agostinelli Best BPM Dissertation Award , The PhD thesis of Simone Agostinelli titled Generating Executable Robotic Process Automation Scripts from Unsegmented User Interface Logs (https://ceur-ws.org/Vol-3469/paper-01.pdf) won the 2023 Best BPM Dissertation Award at the 21st International Conference on Business Process Management (BPM 2023). The pdf of the thesis is available here: https://iris.uniroma1.it/bitstream/11573/1661397/1/Tesi_dottorato_Agostinelli .pdf
- Marco Temperini Best Paper Award, The Best Paper AwardThe following paper is conferred as the best paper award of the above conference for its innovative contribution in terms of originality of concepts and application.“Boulez: A Chatbot-based Federated Learning System for Distance Learning”Author(s): Stefano D'urso, Filippo Sciarrone, Marco TemperiniConference Track: IV2023: Learning Analytics27th International Conference on Information Visualization, 25 – 28 July 2023, Tampere University ● Finland
- Best Paper Award, The Best Paper AwardThe following paper is conferred as the best paper award of the above conference for its innovative contribution in terms of originality of concepts and application.“Boulez: A Chatbot-based Federated Learning System for Distance Learning”Author(s): Stefano D'urso, Filippo Sciarrone, Marco TemperiniConference Track: IV2023: Learning Analytics27th International Conference on Information Visualization25 – 28 July 2023Tampere University ● Finland
- Marco Temperini Best Reviewer Award, presented byIEEE Technical Committee on Learning TechnologyIn recognition for providingdetailed and constructive reviews consistently for the manuscripts submittedat 23rd IEEE International Conference on Advanced Learning Technologies (ICALT 2023),Orem, UT, USA, during July 10 to 13, 2023.

2.9 Contracts

Researches carried on at DIAG are funded by public agencies and/or companies. Some of them span over many years. For each contract, we list below contractor, funding (in Euro), title, project leader, and duration. Titles of contracts funded by Italian entities are reported in Italian.

European Union (EU)

- H2020 - A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems, Daniele Nardi , € 741.888,75 , ending 31-12-2024
- HORIZON-EIC - A Novel EEG Ultrasound Device for Functional Brain Imaging and Neurostimulation, Laura Astolfi , € 341.609,14 , ending 28-02-2027
- H2020-ERC - Algorithmic and Mechanism Design Research in Online MArkets, Stefano Leonardi , € 1.780.150,00 , ending 30-06-2024
- DIGITAL-2021-EDIH-01 - Digital Solutions for a Healthy, Active and Smart Life, Alberto Marchetti-Spaccamela , € 74.765,95 , ending 30-09-2025
- ERASMUS-EDU-2022-PEX-EMJM-MOB - Erasmus Mundus Joint Master In Artificial Intelligence, Massimo Mecella , ending 31-10-2028
- H2020 - Integrated Infrastructure for Social Mining and Big Data Analytics, Aris Anagnostopoulos , € 220.000,00 , ending 31-12-2024
- HORIZON-INFRA-2021- - SoBigData Research Infrastructure Preparatory Phase Project, Aris Anagnostopoulos , € 46.562,50 , ending 30-09-2025
- Agence Nationale de la Recherche (ANR) - Telemedicine and precision medicine: The role of data in healthcare innovation, ending 30-06-2025
- H2020-ICT-2019-3 - Towards a vibrant European network of AI excellence centres, Maurizio Lenzerini , € 308.175,00 , ending 31-08-2024
- H2020-ERC - White-Box Self-Programming Mechanisms, Giuseppe De Giacomo , € 2.499.197,00 , ending 31-10-2024
- Sapienza Università di Roma - WhiteMech: White-box Self-Programming Mechanisms, ERC Advanced Grant, Giuseppe De Giacomo , € 2.499.197, ending 31-10-2024

Italian Fundings

- Ministero Salute - Academic, open label, phase I clinical trial on the use of fresh, allogeneic CD19-CAR T cells for treatment of children with relapsed/refractory B-cell Acute Lymphoblastic Leukemia, Giulia Fiscon , € 64.460,00 , ending 29-04-2026
- MISE - Scienze della vita - Cloud plAtform for intelligent prevention and Diagnosis sUpported by artifiCial intelligEnce solutiOns , Francesco Delli Priscoli , € 698.125,00 , ending 31-12-2024
- Ministero Salute - DiSCIoser: Unlocking recovery potential of arm sensorimotor functions after spinal cord injuryby promoting activity-dependent brain plasticity and modeling the causal relationship betweenbrain plasticity and recovery of function, Febo Cincotti , € 90.000,00 , ending 31-05-2024
- Ministero Salute - POS - Ecosistema uRbano per l'invecchiaMEnto attivo e in Salute, Tiziana Catarci , € 178.450,16 , ending 12-02-2027
- INAIL - BRIC 2022 - GURU: Sviluppo di un sistema multisensoriale a realtà mista per l'addestramento dinamico di lavoratori in ambienti ad alto rischio, Pietro Arico' , € 109.945,00 , ending 01-05-2025
- Ministero Salute - INTER-RO-GAIT. Patient-therapist INTERaction during RObotic GAIT rehabilitation after Spinal Cord Injury: clinical, instrumental and hyperscanning study , Jlenia Toppi , € 80.278,00 , ending 31-05-2024

- Ministero della Salute - The PROMOTOER: a Brain Computer Interface-based intervention that promotes upper limb functional motor recovery in subacute stroke patients., Febo Cincotti , € 53889, ending 01-12-2025

MUR-PRIN

- PRIN 2020 - Acting together: how motor styles shape action prediction and brain-to-brain connectivity in typical and autistic populations, Laura Astolfi , € 281.498,00 , ending 31-05-2025
- PRIN 2022 - Artificial Intelligence algorithms to track and detect Covid-19 vaccine-related infodemic on social media., Umberto Nanni , € 97.000,00 , ending 15-10-2025
- PRIN 2022 - BIODRONES – Biomimetic and Innovative Optimized hydrodynamic concepts of high-efficiency underwater gliding DRONES for ocean research, Giampaolo Liuzzi , € 60.760,00 , ending 27-09-2025
- PRIN 2022 - Class-tAIs: Artificial Intelligence and multi-brain connectivity as a buddy to Enhancing Competencies in students, Laura Astolfi , € 61.128,00 , ending 27-09-2025
- PRIN 2022 - Conversational Agents: Mastering, Evaluating, Optimizing, Giuseppe Santucci , € 54.272,00 , ending 27-09-2025
- PRIN 2020 - CRoss-modal understanding and gEnerATIon of Visual and tExtual content, Roberto Navigli , € 321.846,00 , ending 31-05-2025
- PRIN 2022 - Defining gene regulation and coregulation at single cell resolution in grapevine, Paola Paci , € 57.181,00 , ending 27-09-2025
- PRIN 2022 - Discount quality for responsible data science: Human-in-the-Loop for quality data, Tiziana Catarci , € 48.800,00 , ending 27-09-2025
- PRIN 2022 - EdgeVision against Varroa (EV2): Edge computing in defence of bees, Roberto Beraldi , € 83.987,00 , ending 27-09-2025
- PRIN 2022 - Integrating cutting-edge tools for targeted approach to patients with adrenocortical tumors (COOL-REACT), Manuela Petti , € 44.400,00 , ending 15-10-2025
- PRIN 2022 - ISIDE: Intelligent Systems for Infrastructural Diagnosis in smart-concretE, Christian Napoli , € 72.232,00 , ending 27-09-2025
- PRIN 2022 - Learning in Markets and Society, Stefano Leonardi , € 60.977,00 , ending 27-09-2025
- PRIN 2022 - Logical methods in combinatorics, Nicola Galesi , € 72.511,00 , ending 27-09-2025
- PRIN 2022 - Motown: Smart Production Planning and Control for Manufacturing of Electric Vehicle Powertrain in Industry 4.0 Environment, Andrea Marrella , € 35.776,00 , ending 27-09-2025
- PRIN 2022 - NEural REasoning over Open data (NEREO), Fabrizio Silvestri , € 112.160,00 , ending 27-09-2025
- PRIN 2022 PNRR - Neurophysiological characterization and modelling of “fitness to work”, for enhanced training in virtual reality and safer , Pietro Arico' , € 151.886,00 , ending 30-11-2025
- PRIN 2022 - POLAR: POLicy specificAtion and enfoRcement for privacy-enhanced data management, Riccardo Rosati , € 55.000,00 , ending 27-09-2025

- MIUR - PRIN 2020 - Resilient AI-Based Self-Programming and Strategic Reasoning (RIPER), Giuseppe De Giacomo , € 275.000, ending 01-06-2025
- PRIN 2022 - Protecting the Environment: Advances in Circular Economy (PEACE), Idiano D'Adamo , € 27.830,00 , ending 27-09-2025

Regione Lazio

- DTC - Fase 2 - Cicero-Net -- La rete turistica dei luoghi di Cicerone, Andrea Marrella , € 28.565,95 , ending 18-01-2024
- FESR Lazio 2021-2027 - RIposizionamento competitivo - Digital Twin City, Thomas Alessandro Ciarfuglia , € 80.942,89 , ending 31-05-2025
- FESR Lazio 2021-2027 - RIposizionamento competitivo - Modular Early Threat Identification System, Silvia Bonomi , € 144.691,28 , ending 31-05-2025
- PROGETTI GRUPPI DI RICERCA 2020-POR FESR Lazio 2014-2020 - Piattaforma Intelligente PEr l'ottimizzazione di operazioni di Riciclo, Laura Palagi , € 53.937,91 , ending 14-04-2024
- DTC - Fase 2 - Sistema Cartografico Informatizzato della Bibliografia Archeologica del Lazio, Massimo Mecella , € 28.100,10 , ending 18-01-2024

3 Research Areas

The scientific activities of the Department cover six Research Areas, responsible for identifying and coordinating research programs and for supporting teaching activities. Each area includes one or several research groups. Research areas are:

- Biomedical Engineering
- Engineering in Computer Science
- Economics and Management Engineering
- Operations Research
- Systems and Control Engineering

3.1 Biomedical Engineering

3.1.1 Bioengineering and Bioinformatics

Research lines:

- Analysis and Modelling of Metabolic Systems
- Bioengineering for Molecular Biology and Bioinformatics
- Methods and Techniques for Neuroengineering
- Processing and analysis of bioelectrical signals

Members: ARICO' Pietro, ASTOLFI Laura, CINCOTTI Febo (leader), COLAMARINO Emma, FARINA Lorenzo, FISCON Giulia, PACI Paola, PETTI Manuela and TOPPI Jlenia

Post Docs: DE SETA Valeria, PUXEDDU Maria Grazia, RONCA Vincenzo and SIBILIO Pasquale

PhD students: MONGIARDINI Elena, QUATTROCIOCCHI Ilaria and RANIERI Andrea

The research activity in this area deals with the applications of the general methodologies of modelling, estimation, signal processing, machine learning and statistics to the study of physiological, biological and biomolecular systems. Research activities date back to the 70's when novel mathematical models of the human digestive system were proposed. Modelling of physiological systems, including insulin secretion and glucose metabolism, has been the main research activity in the following two decades. Novel methodologies in the analysis of neuroelectrical signals to study the human brain functions have been proposed since the 2000's. Later in the same decade the research interest included the new fields of computational modeling and analysis of omics data. At present, the group is engaged in a multidisciplinary effort, pursuing a wide range of research topics by developing mathematical methods applied to neurophysiology, to the analysis and integration of omics data for precision and network medicine, and by designing innovative instrumentation for neurorehabilitation. The main research topics are:

- Design and validation of EEG-based Brain-Computer Interfaces for assistive and rehabilitation purposes;
- Design and validation of Passive Brain-Computer Interfaces (pBCIs) for mental and emotional states evaluation in operational environments;

- Computational modeling and analysis of omics data for precision and network medicine.
- Estimation of brain connectivity in humans by means of structural and functional models and applications;
- Neuroelectrical hyperscanning and social neuroscience;
- Bioinformatics

Research goals include:

- application of Brain-Computer Interfaces (BCIs) as support to rehabilitation of stroke patients;
- application of passive Brain-Computer Interfaces (pBCIs) in out-of-the-lab applications, especially in operational environments (e.g. aviation, automotive, industrial workers);
- optimization of tumor radiotherapy, the development of computational and bioinformatic tools for the analysis of omics data in different organisms and diseases, including berry developments in plants and human solid tumors.
- use of features extracted from human neuroelectrical activity and connectivity to identify biomarkers of diseases and of physiological mental states
- drug repurposing
- use of bioelectrical signals as biometric features for identification purposes in cybersecurity applications
- identification of disease modules in omics networks

The research group participates in the joint translational research platform established by Sapienza University and IRCCS Fondazione Santa Lucia. Several other national and international cooperations are actually active, among which: Laboratori di Neuroscienze Industriali - Dip. di Medicina Molecolare, Sapienza Universit√† di Roma; Dip. di Fisiologia Umana e Farmacologia, Sapienza Universit√† di Roma; Dip. di Biotecnologie Cellulari ed Ematologia, Sapienza Universit√† di Roma; Dip. di Medicina sperimentale, laboratorio di Oncogenomica, Sapienza Universit√† di Roma, Laboratorio di Oncogenesi Molecolare, Istituto Nazionale Tumori Regina Elena (Roma); Istituto di Analisi dei Sistemi e Informatica (IASI) - CNR (Roma); Dipartimento di Ingegneria Industriale, Universit√† degli studi di Napoli, Federico II; Laboratorio di Genetica Agraria, Dipartimento di Biotecnologie, Universit√† di Verona; Institute of Medical Statistics, Computer Sciences and Documentation, Friedrich Schiller University, Jena, Germany; Functional Brain Mapping Laboratory, University of Geneva, Switzerland; Perceptual Networks Group, University of Fribourg,Switzerland; Computational Cognitive Neuroscience Lab, Indiana University, Bloomington, USA; New Zealand Brain Research Institute, Christchurch, New Zealand, Department of Medicine - Harvard University (USA), Channing division of Network Medicine, Harvard University (USA), Universit√† Campus Bio-Medico di Roma, Martinos Center for Biomedical Imaging - Harvard Medical School, Massachusetts General Hospital. Facilities available for research and teaching activities include:

- The laboratory of Bioengineering and Bioinformatics (BiBiLab), located in the premises of the Department
- The laboratory of Neuroelectrical Imaging and Brain Computer Interfaces (NEILab), located in the premises of Fondazione Santa Lucia (accessed as part of the joint research platform)

Publications

Journal papers

Mezi Silvia, Pomati Giulia, Fiscon Giulia, Amirhassankhani Sasan, Zizzari Ilaria Grazia, Napoletano Chiara, Rughetti Aurelia, Rossi Ernesto, Schinzari Giovanni, Tortora Giampaolo, Lanzetta Gaetano, D'amati Giulia, Nuti Marianna, Santini Daniele, Botticelli Andrea "A network approach to define the predictive role of immune profile on tumor response and toxicity of anti PD-1 single agent immunotherapy in patients with solid tumors". In: *Frontiers In Immunology*, (volume: 14) (2023). DOI: 10.3389/fimmu.2023.1199089

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Botticelli Andrea, Cirillo Alessio, Pomati Giulia, Cortesi Enrico, Rossi Ernesto, Schinzari Giovanni, Tortora Giampaolo, Tomao Silverio, Fiscon Giulia, Farina Lorenzo, Scagnoli Simone, Pisegna Simona, Ciurluini Fabio, Chiavassa Antonella, Amirhassankhani Sasan, Ceccarelli Fulvia, Conti Fabrizio, Di Filippo Alessandra, Zizzari Ilaria Grazia, Napoletano Chiara, Rughetti Aurelia, Nuti Marianna, Mezi Silvia, Marchetti Paolo "Immune-related toxicity and soluble profile in patients affected by solid tumors: a network approach". In: *Cancer Immunology, Immunotherapy*, (2023). DOI: 10.1007/s00262-023-03384-9

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and Face-to-Face Lessons: A Case Study at Driving School". In: *Brain Sciences*, (volume: 13) (2023). DOI: 10.3390/brainsci13010095

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3.2 Engineering in Computer Science

3.2.1 Algorithms and Data Science

Research lines:

- Algorithmic Data Analysis
- Algorithmic Game Theory
- Algorithms
- Big Data
- Data Mining
- Data Science
- Economics and Computation
- Mechanism Design
- Network and Stochastic Processes
- Random Structures
- Recommender Systems
- Social Networks
- Streaming

Members: ANAGNOSTOPOULOS Aris, BECCHETTI Luca, FUSCO Federico, LEONARDI Stefano (leader), SICILIANO Federico, SILVESTRI Fabrizio, TRAPPOLINI Giovanni, FAZZONE Adriano *(Former)* and MARCHETTI-SPACCAMELA Alberto

Post Docs: BARNABò Giorgio *(Former)*, BUCARELLI Maria Sofia, BIRMPAS Georgios, EZRA Tomer, LAZOS Philip *(Former)* and REIFFENHAUSER Rebecca *(Former)*

PhD students: GENTILI Michele *(Former)*, MARTINI Leonardo *(Former)*, MASTROPIETRO Andrea and RUSSO Matteo

The focus of the Algorithms and Data Science group is on theoretical and applied research in the areas of algorithms and data science. The main focus in on the design of algorithmic techniques for the analysis of very large volumes of data and for the economics of the internet, as well as in the algorithmic modeling of complex systems.
The group is particularly active in the following areas:

- Algorithmic Fairness
- Algorithmic Game Theory and Mechanisms Design
- Approximation and Online Algorithms
- Distributed and Streaming Computation
- Internet Economics
- Large-Scale Data Mining
- Online Learning
- Social Network Analysis
- Submodular Optimization
- Theory and Applications of Machine Learning.

Publications

Journal papers

Grani Giorgio, Gentili Michele, Siciliano Federico, Albano Domenico, Zilioli Valentina, Morelli Silvia, Puxeddu Efisio, Zatelli Maria Chiara, Gagliardi Irene, Piovesan Alessandro, Nervo Alice, Crocetti Umberto, Massa Michela, Teresa Samà Maria, Mele Chiara, Deandrea Maurilio, Fugazzola Laura, Puligheddu Barbara, Antonelli Alessandro, Rossetto Ruth, D'amore Annamaria, Ceresini Graziano, Castello Roberto, Solaroli Erica, Centanni Marco, Monti Salvatore, Magri Flavia, Bruno Rocco, Sparano Clotilde, Pezzullo Luciano, Crescenzi Anna, Mian Caterina, Tumino Dario, Repaci Andrea, Grazia Castagna Maria, Triggiani Vincenzo, Porcelli Tommaso, Meringolo Domenico, Locati Laura, Spiazzi Giovanna, Di Dalmazi Giulia, Anagnostopoulos Aristidis, Leonardi Stefano, Filetti Sebastiano, Durante Cosimo "A Data-Driven Approach to Refine Predictions of Differentiated Thyroid Cancer Outcomes: A Prospective Multicenter Study". In: *The Journal Of Clinical Endocrinology And Metabolism*, (2023). DOI: 10.1210/clinem/dgad075

Wang Xu-wen, Madeddu Lorenzo, Spirohn Kerstin, Martini Leonardo, Fazzone Adriano, Becchetti Luca, Wytock Thomas P, Kovács István A, Balogh Olivér M, Benczik Bettina, Pétervári Mátyás, Ágg Bence, Ferdinandy Péter, Vulliard Loan, Menche Jörg, Colonnese Stefania, Petti Manuela, Scarano Gaetano, Cuomo Francesca, Hao Tong, Laval Florent, Willems Luc, Twizere Jean-claude, Vidal Marc, Calderwood Michael A, Petrillo Enrico, Barabási Albert-lászló, Silverman Edwin K, Loscalzo Joseph, Velardi Paola, Liu Yang-yu "Assessment of community efforts to advance network-based prediction of protein-protein interactions". In: *Nature Communications*, (volume: 14) (2023). DOI: 10.1038/s41467-023-37079-7

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3.2.2 Artificial Intelligence and Knowledge Representation

Research lines:

- Description Logics
- Logics for AI
- Reasoning about Actions and Planning
- Semantic Technologies
- Spoken Language Understanding

Members: CIMA Gianluca, CONSOLE Marco, DE GIACOMO Giuseppe, LEMBO Domenico, LENZERINI Maurizio, LIBERATORE Paolo, NARDI Daniele, NAVIGLI Roberto, PATRIZI Fabio, POGGI Antonella, ROSATI Riccardo (leader), SCAFOGLIERI Federico Maria and UMILI Elena

Post Docs: CROCE Federico

PhD students: ANDOLFI Luca, BRUNORI Damiano, CHIARIELLO Francesco, CIPOLLONE Roberto, DELFINO Roberto Maria, FUGGITTI Francesco, MARCONI Lorenzo, NAMICI Manuel, PALUDO LICKS Gabriel, PARRETTI Gianmarco, SILO Luciana, TRAPASSO Alessandro and VALENTINI Riccardo

Research in Artificial Intelligence at DIAG started in the early 80s and established this research group as one of the most prominent ones in the field of logic-based knowledge representation and automated reasoning. Research has been conducted in many areas, with several outstanding results. The research lines presently active are described in the following.

Description Logics (DL) form a family of Logic-based Knowledge Representation Languages which allow for modeling an application domain in terms of objects, concepts and relationships between concepts, and for reasoning about them. They are widely used in several areas, including ontology engineering, Semantic Web, and information integration. The research at DIAG on DL has a long tradition, and focuses on many relevant aspects, including algorithms for automated reasoning, trade-off between expressive power and computational complexity of reasoning, query answering in DL knowledge bases, adding both monotonic and non-monotonic rules to DL. In the future, the work on DL will both continue along the above mentioned lines and focus on dynamic aspects, such as update and revision of DL knowledge bases, and reasoning about programs expressed on such knowledge bases.

The Semantic Technologies aim at intelligent information processing by creating and connecting machine-understandable information, sometimes called the Semantic Web. Our research in this area mainly focuses on representation languages, in particular for ontologies. A remarkable outcome of our research in this area is the standardization of the OWL 2 QL ontology specification language by the World Wide Web Consortium. OWL 2 QL directly derives from DL-Lite, a family of ontology formalisms which we proposed and studied in our recent research in this field.

Reasoning about Actions concerns the theory and the implementation of agents that reason, act and perceive in changing, incompletely known, and unpredictable environments. Such agents must have higher-level cognitive functions that involve reasoning, for example, about goals, actions, when to perceive and what to look for, the cognitive states of other agents, time, collaborative task execution, etc. Our research on Reasoning about Actions focuses on several aspects, including: foundations of the theory of actions; various forms of planning or automated process synthesis for sophisticated dynamic properties, e.g., expressed in mu-calculus, ATL, LTL, LTLf, and LDLf; high-level agent programs, like ConGolog based on the Situation Calculus; agent behavior synthesis and composition. This research is also related with, and applied to, other areas, such as cognitive robotics, multi-agent/multi-robot systems, software service modeling, execution and composition, high-level programs and business processes over ontologies and data sources.

The group is also focusing on Reinforcement Learning in the presence of non-Markovian Rewards, as well as on using logic-based abstraction and prior knowledge to improve the performance of the learning process.

One specific application where knowledge representation has been applied is Spoken Language Understanding in the context of Robotics. Specifically, we have addressed the interpretation of spoken commands and the extension to handle more complex forms of dialog. The knowledge about the environment and the robot capabilities are used by the system in order to build the language that specifies robot commands. Moreover, the knowledge about the environment (semantic map), can be used to bias the interpretation of commands through a spoken language command interpretation chain that is based on statistical off-the-shelf tools.

Finally, the group also investigates the synergistic integration of Natural Language Processing and Knowledge Representation.

Several group members are recipients of prestigious awards, are regularly involved in editorial activities of the scientific community, and are invited to deliver keynote talks at international conferences or workshops.

Guests:

- Prof. Yves Lesperance (whole 2023)
- Prof. Sebastian Sardina from RMIT Melbourne, Australia (visiting period: Nov 9 - Dec 21, 2023)

Publications

Journal papers

Cima G., Console M., Lenzerini M., Poggi A. "A review of data abstraction". In: *Frontiers In Artificial Intelligence*, (volume: 6) (2023). DOI: 10.3389/frai.2023.1085754

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Gaillard Pierre, Patrizi Fabio, Perelli Giuseppe "Strategy Repair in Reachability Games". In: *European Conference On Artificial Intelligence*, (2023), pp. 780 - 787. DOI: 10.3233/FAIA230344

3.2.3 Artificial Intelligence and Robotics

Research lines:

- Artificial Intelligence and Robotics
- Cognitive Robotics
- Human-Robot Interaction
- Information Fusion
- Mobile Robot Navigation
- Multi-Agent and Multi Robot Systems
- Reinforcement Learning
- Robot Competitions and Benchmarking
- Robot Perception
- Robot Security
- Semantic Knowledge for Robots
- Sensor Calibration
- Simultaneous Localization and Mapping
- Social Robotics

Members: BERNARDINI Sara, CIARFUGLIA Thomas Alessandro, GRISETTI Giorgio, IOCCHI Luca, NAPOLI Christian, NARDI Daniele (leader) and UMILI Elena

Post Docs: DI GIAMMARINO Luca, BRIGATO Lorenzo *(Former)*, CARBONE LORIO Carlos Salvador *(Former)*, RICCIO Francesco *(Former)* and WANG Lun *(Former)*

Affiliated: CAPOBIANCO Roberto

PhD students: ANTONIONI Emanuele *(Former)*, ARGENZIANO Francesco, BAZZANA Barbara, BRANDIZZI Nicolo', BRIENZA Michele , BRIZI Leonardo, BRUNORI Damiano, CATACORA OCANA Jim Martin, CERIOLA Davide, DE MAGISTRIS Giorgio, DE REBOTTI Lorenzo, DI VALERIO Federico, FANTI Andrea, FAWAKHERJI Mulham *(Former)*, FEOLA Luigi *(Former)*, FERRARI Simone, FRATTOLILLO Francesco, GALLETTI Martina, KASZUBA Sara *(Former)*, LA ROSA Biagio *(Former)*, MOTOI Ionut Marian, PONZI Valerio, PROIETTI Michela, RAGNO Alessio, SABBELLA Sandeep Reddy, SALADINO Alessio, SALEM Omar Ashraf Ahmed Khairy, SARACENI Leonardo, SCHLEGEL Dominik *(Former)*, SURIANI Vincenzo *(Former)*, TIBERMACINE Imad Eddine, TRAPASSO Alessandro and YOUSSEF ALI *(Former)*

The research in this area is at the intersection between Artificial Intelligence and Robotics, and has its roots in the early AI research that targeted robots as embodiments of the intelligent agent.

The key scientific challenge, which has received a significant push by the recent devel- opments in sensor technology and robotics, is the ability to deal with manifold represen- tations of knowledge that enable robots to perform complex tasks in a dynamic, unknown environment populated by other (robotic and human) agents. One section of the work aims at analizing perceptual data to create a rich world model, through the interpretation of sensor data and/or data coming from other information sources, including spoken lan- guage understanding. Another section of the research aims at developing various types of inference to support the actions of the robot in the environment, in particular within social contexts and in the interaction

with the user. Both perception and action are often addressed in scenarios where multiple agents cooperate both in distributed perception and in task execution.

The research group builds on the experience acquired through robotic competitions in the context of RoboCup, started back in 1998, not only in robot soccer, but also in Res- cue, @Home and @Work competitions. Hence, one characterizing aspect of the research approach is a strong emphasis on the experimental validation of the proposed technical solutions through the implementation of system prototypes and their evaluation through suitable benchmarking methodologies.

The application domains, where the research ideas have been tested and experimen- tally evaluated, include virtual agents and multi-robot systems in soccer, emergency re- sponse robots, surveillance, agriculture and service robots. Specifically, the problem of sensor fusion and situation awareness has been targeted in the framework of maritime surveillance.

Several open-source hardware and software components and data sets are released and listed in our Web site www.diag.uniroma1.it/~labrococo. They include the design of a small mobile robot MARRtino, the software libraries Petri Net Plans, soccer robot vision applications (GNAO), IMBS, PHIS, PTracking, NICP, IMU-TK, D2CO, Easy-DepthCalibration, and the data sets data sets for maritime surveillance (MarDT), and the spoken language processing chain LU4R (in collaboration with Univ. Tor Vergata) and the data set for spoken command understanding (Huric).
The group has a solid tradition of cooperation with other research groups worldwide, and is very interested in establishing new collaborations and hosting foreign researchers and students.

Publications

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3.2.4 Computer Networks and Pervasive Systems

Research lines:

- Augmented Reality
- Blockchain Technologies
- Decentralized Applications
- Fog Computing
- Internet of Things
- Networks of Resource Constrained Devices
- Parallel and Distributed Computing Platforms
- Self-* Protocols and Systems
- Wireless and Sensor Networks

Members: BECCHETTI Luca, BERALDI Roberto, CHATZIGIANNAKIS Ioannis (leader), PROIETTI MATTIA Gabriele, QUERZONI Leonardo, VITALETTI Andrea and MARCHETTI-SPACCAMELA Alberto

PhD students: JIMENEZ GUTIERREZ Daniel Mauricio and MILANI Stefano

The group is conducting research on emerging networking technologies and modern pervasive systems. Our research in these areas involves both theoretical investigations and practical implementations. We work closely with industry partners to design and deploy real-world networking solutions that leverage these emerging technologies. The research activity is supported by the Wireless Sensor Networks Laboratory.
Theories, models, and algorithms: Models for dynamic networks; hierarchical and heterogeneous networks; fast-evolving networks; network dynamics; network growth and evolution; epidemic processes; population protocols; complex networks; scale-free algorithms; local algorithms; applied machine learning; federated learning.
Domain-specific challenges and novel applications: urban/mobile crowdsensing & intelligence; pervasive systems for healthcare and well-being; smart water metering services; cyber-physical pervasive systems; smart homes and virtual assistants; mixed reality; pervasive AR/VR; smart vehicles; disaster sensing and management.
Technological innovations: architectures, protocols, and technologies for pervasive communications; stream processing; cloud-edge processing continuum; resource allocation in fog computing; energy-harvesting, energy-transfer, self-powered, or battery-less systems; mobile and wearable systems; smart devices and environments; positioning, navigation, timing, and tracking technologies; device-free human sensing; blockchains and smart contracts.

Publications

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3.2.5 Computer Vision, Computer Graphics, Deep Learning

Research lines:

- Action and Activity Recognition
- Activity Understanding from 3D data
- Anticipation and Forecasting
- Augmented Reality
- Forensics
- Gesture Recognition
- Human Motion Analysis
- Machine learning and AI security
- Memory and next step prediction in Long Short Time Memory (LSTM) Networks
- Physics based methods
- Scene Representation
- Visual Search and Execution Monitoring

Members: AMERINI Irene, BERALDI Roberto, PROIETTI MATTIA Gabriele, RUSSO Paolo and SCHAERF Marco (leader)

Affiliated: PIRRI Fiora (Former)

Post Docs: MAIANO Luca

PhD students: BONAVENTURA Tania Sari, MAJID Taiba, MANGANELLI CONFORTI Pietro, MAURO Lorenzo, MELIS TONTI Claudia and PAPA Lorenzo

The Computer Vision, Computer Graphics, Deep Learning group is a multidisciplinary team of researchers that investigates several knowledge areas in vision and apply them to scientific problems in many contexts.
The team works on several topics related to Computer Vision, Pattern Recognition, Deep Learning, Multimedia applied to optical images and videos as well as data from different sensors and Computer Graphics.
Some of the topics covered are the following: Edge-Vision and Efficient deep learning, Multimedia Forensics and Deepfake detection, Deep Learning for image and video analysis, Visual Knowledge acquisition: Activity Recognition & Object Detection, Computer Graphics and Point cloud representation, Monocular Depth Estimation, Energy aware deep learning models and Green AI (Beekeeping and Vertical farming), Adversarial Machine Learning.

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Lightweight DL models for resource constraints device — Investigating both mathematically and practically, research areas related to the efficiency of DL models for computer vision tasks. More in detail, the objective is to theoretically analyze and investigate the behavior of fundamental components for neural network learning mechanisms, with a focus on specific layers and elements that characterize the learning procedure, such as self-attention, knowledge distillation, and optimizers. More in detail, computationally efficient solutions are developed in the fields of perception and security, i.e., studying efficient techniques in well-known tasks like monocular depth estimation, 3D mesh reconstruction, and deepfake

detection. Additionally, the key elements of neural network efficiency is analyzed, such as inference time, energy consumption, and their trade-off with estimation performances.
Multimedia forensics and deepfake detection — Multimedia Forensics includes a set of scientific techniques recently proposed for the analysis of multimedia signals (audio, videos, images) in order to recover probative evidences from them; in particular, such technologies aim to reveal the history of digital contents, such as identifying the acquisition device that produced the data, validating the integrity of the contents and retrieving information from multimedia signals. With our research, we seek to study these models to create defense solutions against disinformation attacks based on diffusion models and generative techniques.
Action and Activity Recognition, Anticipation and Forecasting — Different works in literature afford the problem of Actions and Activities Recognition, Anticipation and Prediction in videos. The complexity of the problem requires the consideration of many aspect. First of all, the recognized action sequence has to be consistent with the final task of the whole activity. Furthermore, much attention needs to be given to the prediction of the correct action in those instances where specific sequences are under represent in the dataset not because of the likelihood of them to happen. Finally, several implementation problems, caused by the large dimension of the data used, need to be addressed. Our researched work focused on tackling those problems producing a novel network, the Anticipation and Forcasting Network.
Object Detection and Instance Segmentation — Object detection is the task of detecting instances of certain object classes (such as humans, buildings or cars) in digital images and videos. Well-researched sub-tasks include face detection and pedestrian detection. Instance segmentation is the task of grouping parts of the image that belongs to the same entity or class. In the field of research that combines Object Detection and Instance Segmentation, a new approach is proposed: from the classical machine learning algorithms, the research community moved to a neu ral network approach via the use of several new architecture. Our research focused on developing new architectures by improving performances, computation time, capacity and multi-tasking properties.
Edge and Fog Computing — Distributed algorithms are stutied, resource-sharing strategies, and scheduling policies that best fit this new kind of computing paradigm. We have expertise in the mathematical modeling of the problem, simulation tools and in modern technologies like Docker and Kubernetes.
Impact of adversarial and backdoor attacks on deep learning techniques — In the last couple of decades, machine learning and neural networks applications have quickly become the state of the art in every automated task. Moreover, the spreading of high-performance GPUs at an affordable price, along with the creation of frameworks that are always simpler to use, have made the implementation of neural network architectures accessible to everyone.
Nevertheless these techniques have been found to be highly exposed to malicious approaches. Malicious approaches usually refer to an adversarial scenario, in which an attacker tries to exploit vulnerabilities of a system in order to gain advantages from it.

Publications

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3.2.6 Cybersecurity

Research lines:

- Application security
- Blockchain Technologies
- Blockchains and distributed ledger security
- Cloud security
- Cyber physical systems security
- Data privacy and security
- Distributed systems security
- Economics of security and privacy
- Embedded systems security
- Hardware security
- Machine learning and AI security
- Malware Analysis
- Mobile security
- Network and systems security
- Protocol security
- Robot Security
- Secure and robust distributed systems
- Security and privacy for the Internet of Things
- Security and privacy metrics
- Security architectures
- Security awareness
- Security for cyber-physical systems
- Security governance
- Threat intelligence
- Usable security and privacy
- Web security

Members: AMERINI Irene, BERALDI Roberto, BONOMI Silvia, CATARCI Tiziana, D'AMORE Fabrizio, D'ELIA Daniele Cono, DELLI PRISCOLI Francesco, DI GIORGIO Alessandro, DI LUNA Giuseppe Antonio, IOCCHI Luca, LAZZERETTI Riccardo, LEMBO Domenico, MECELLA Massimo, PIETRABISSA Antonio, QUERZONI Leonardo (leader), ROSATI Riccardo, SANTUCCI Giuseppe, VISCONTI Ivan, ANGELINI Marco, COPPA Emilio, DEMETRESCU Camil *(Former)* and MARCHETTI-SPACCAMELA Alberto

Post Docs: BORZACCHIELLO Luca *(Former)*, BRIGATO Lorenzo *(Former)* and TORTORELLI Andrea

PhD students: ARTUSO Fiorella, ASSAIANTE Cristian, BARDHI Enkeleda *(Former)*, BORRELLO Pietro *(Former)*, BOTTURA Nicola, CAPOZZI Gianluca, CARELLO Maria Patrizia, CONSOLE Francesca, CUOCI Marco, DI PIETRO Giorgia, FERRACCI Serena *(Former)*, IZZILLO Alessio, MARINI Matteo, PALMA Alessandro and PRIAMO Giacomo

The cybersecurity group is a multidisciplinary team of researchers that collates several knowledge areas and apply them to scientific problems in the context of IT security. The team works on several diverse topics related to cybersecurity, including:

Attack modeling. Among all the existing Attack models, Attack graphs represent a nice abstraction to capture the notion of multi-step attack i.e., an attack toward a specific target executed taking intermediate steps in which the attacker compromises several entireties and exploits their vulnerability to reach the target. Several attack graph representations exist in literature but they suffer the same limitation: they are poorly scalable and consider only vulnerability related to the underlying network infrastructure. We study how to improve the scalability of the attack graph generation process and how to enrich the attack graph with other types of information (e.g., application vulnerabilities, human vulnerabilities, etc.).

Representation models for binary code. The exponential growth of the internet of things and the related growth of firmware require automated techniques that could scale and analyze thousands of binaries in a short amount of time. The Cybersecurity group at DIAG has a keen interest in developing techniques to represent and analyze binaries using Deep Neural Networks. Specifically, it has an experience on the problem of binary similarity (recognize if two binaries share some similarities) and automated function naming (assign automatically meaningful names to snippets of binary code). These works are carried out in collaboration with companies and other universities.

Blockchain. Blockchain is an emerging paradigm that allows storing data in a fully decentralized system guaranteeing data integrity and transparency in the data flow. Actually, several technologies exist that allow users to develop and deploy his/her own blockchain. We are studying issues related to blockchain scalability (in terms of achieved performance) and security against external attacks.

Cyber-physical systems. Protection and preventive control of cyber-physical systems (including robots) via model-based control-theoretical approaches and machine learning approaches. Robust control and model predictive control are being utilized to safely operate complex systems, such as SCADA controlled Critical Infrastructures (e.g., Power Networks), in order to assure service resilience and operational efficiency. On a related research line, we study novel solutions for the protection of IoT devices from external malicious interactions based on the behavioral analysis of the attacker. Finally, we exploit machine learning (in particular, unsupervised or semi-supervised methods) to detect anomalies in complex cyber-physical systems, including robots interaction with people in public environments.

Analysis-Resistant Code. We develop methodologies and tools for both anticipating attackers and helping defenders, as in: program analyses for adversarial code showing anti-analysis techniques, code protection methods against reverse engineering attacks, identification of transparency flaws in popular program instrumentation systems, analysis of payloads encoded using weird-machine abstractions. We strive to build solutions that can meet the day-to-day needs of security professionals (for instance, we developed effective solutions for handling evasive malware that hides its true colors when executing in a controlled environment), and work on cutting-edge instrumentation systems (e.g., dynamic binary instrumentation, virtual machine introspection) and program encoding schemes (such as weird machine abstractions). Malware analysis and software protection are the two most prominent application domains for this strand of research.

Malware Analysis Support Tools. Understanding the behavior of malware requires a semiautomatic approach including complex software tools and human analysts in the loop. However, the huge number of malicious samples developed daily calls for some prioritization mechanism to carefully select the samples that really deserve to be further examined by analysts. This avoids computational resources be overloaded and human analysts saturated. We investigate a malware triage stage where samples are quickly and automatically examined to promptly decide whether they should be immediately dispatched to human analysts or to other specific automatic analysis queues, rather than following the common and slow analysis pipeline.

Privacy Preserving Applications. Private computing provides a clever way to process data without revealing any details about the data itself to the party in charge of processing it. Data protection can be achieved by encrypting the signals and processing them in encrypted form. Possible applications of this approach are virtually endless. Among them, we explore privacy-preserving biometric matching, biomedical signal processing, private sensor fusion in IoT swarms, and private sample analysis for malware identification.

Code Reuse Attacks and Defenses. Code reuse attacks are exploits in which an attacker can execute arbitrary code on a compromised machine without having to inject any instruction in memory, as they achieve the intended behavior by joining fragments of code belonging to a legit software component already present in memory. Return oriented programming (ROP) attacks are the most common form of such attacks. We have been building a collection of ROP exploits of increasing complexity to foster their study in the research community; we also developed a tool for inspecting and analyzing how a ROP attack takes place, which can sometimes be a cumbersome task even for security professionals due to the entanglements of ROP code, and frequently a disheartening one for researchers. We are exploring how to ameliorate the overheads of existing system defenses against code reuse attacks by leveraging monitoring primitives available in the most recent families of processors, as performance is a key factor for their adoption.

Side Channels. Protecting the confidentiality of security-sensitive information in modern computer systems is a requirement more and more challenging to satisfy in the face of increasingly sophisticated microarchitectural side-channel attacks. These attacks allow adversaries to leak information from victim execution by observing changes in the microarchitectural state, typically via timing measurements. We study automatic hardening transformations for software victims such as cryptography libraries subject to timing leaks, and investigate attacks for hardware victims as it is the case with popular transient execution attacks.

Swarm Attestation. Remote attestation protocols are widely used to detect device configuration (e.g., software and/or data) compromise in Internet of Things (IoT) scenarios. Unfortunately, the performances of such protocols are unsatisfactory when dealing with thousands of smart devices. Upon the recent concept of noninteractive attestation, we are approaching the collective attestation problem by reducing it into a minimum consensus one and the results confirm the suitability of such a solution for low-end devices, and highly unstructured networks.

Symbolic execution. In recent years symbolic execution has drawn considerable attention from academic and industrial researchers, with notable applications to, e.g., software testing, program verification, and security. We authored a survey of symbolic execution techniques, reviewing the state of the art in the design, implementation, and open research problems in the area, with particular attention to cybersecurity aspects. We have been researching in memory modeling problems for symbolic executors, proposing a model that

can accurately capture pointer dereferencing operations, which are critical for instance in the detection of vulnerabilities (such as use-after-free and heap overflow) and in turn for their exploitation. We also explored how symbolic execution can help reconstruct the protocol used in Remote Access Trojans, which are weapons used by cybercriminals to control infected endpoints. Finally, we have explored how to effectively run in parallel a symbolic executor and a coverage-guided fuzzer in a hybrid setup in order to find bugs and vulnerabilities in real-world programs.

Visual analytics for cybersecurity. Visual Analytics is the science of analytical reasoning facilitated by visual interactive interfaces. In the cyber-security domain it allows the human to manipulate and manage large quantities of data through powerful visual abstractions, supporting heterogeneous analysis tasks like monitoring, proactive and reactive analysis, what-if analysis and prediction. The support is at different levels, ranging from strategic decision processes down to active cyber-attacks countermeasures. We are actively studying novel visual analytics solutions for cybersecurity, focused on supporting proactive analysis of cyber-risk status for complex networks, real-time response to cyber attacks, effective explanation of learning process for malware classifiers, cybersecurity policy assessment and specification through standard frameworks (e.g. NIST cyber-security framework). Solutions regarding improving situational awareness of cyber-security operators under stressful situations and support to digital forensics activities are currently under development.

Multimedia forensics and security. Multimedia forensics aims to introduce novel methodologies to support clue analysis and to provide an aid for making a decision about sophisticated crimes and terrorist threats by looking at multimedia content as an investigated material. In all cases (e.g., forensic investigations, fake news debunking, information warfare, and cyberattacks) where images and videos serve as critical demonstrative evidence, forensic technologies that help to determine the origin, authenticity of sources, and integrity of multimedia content can become essential tools. For this reason, we are developing technological instruments for verifying image and video origin and authenticity; proposing techniques that basically allow the user to identify forgeries in multimedia objects, distinguishing among deepfake/pristine content and to infer the origin of a digital content at acquisition device and social media level.

The cybersecurity group members are also strongly involved in the activities of the Research Center of Cyber Intelligence and Information Security (CIS). CIS does leadership applied research in the context of cyber security, information assurance, critical information infrastructure protection, trend prediction, open-source intelligence, cyber physical systems and smart complex systems. Advanced capabilities in cyber intelligence will be indeed essential in the next years due to the pervasiveness of cloud, social computing and mobility technologies, that lower the control that organizations and governments have over systems, infrastructure and data. CIS aims at designing better information security methodologies, threat profiles and at elaborating defense strategies taking into account the economic and legal impact in a unique framework. Research results are applied to real world contexts such as cyberwarfare, fraud detection, stock market stability, detection of tax evasion, monitoring of mission-critical systems, early warning systems, and smart environments.

Publications

Journal papers

Maiano Luca, Montuschi Antonio, Caserio Marta, Ferri Egon, Kieffer Federico, Germanò Chiara, Baiocco Lorenzo, Ricciardi Celsi Lorenzo, Amerini Irene, Anagnostopoulos Aristidis "A deep-learning–based antifraud system for car-insurance claims". In: *Expert Systems With Applications*, (volume: 231) (2023). DOI: 10.1016/j.eswa.2023.120644

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Conference proceedings

Carello Maria Patrizia, Marchetti-spaccamela Alberto, Querzoni Leonardo, Angelini Marco "SoK: Cybersecurity Regulations, Standards and Guidelines for the Healthcare Sector". In: *2023 Ieee International Conference On Intelligence And Security Informatics (isi)*, (2023), pp. - 6. DOI: 10.1109/isi58743.2023.10297246

Assaiante C., D'elia D. C., Di Luna G. A., Querzoni L. "Where Did My Variable Go? Poking Holes in Incomplete Debug Information". In: *International Conference On Architectural Support For Programming Languages And Operating Systems - Asplos*, (volume: 2) (2023), pp. 935 - 947. DOI: 10.1145/3575693.3575720

3.2.7 Data Management and Semantic Technologies

Research lines:

- Data cleaning
- Data Integration and Exchange
- Data quality
- Data Warehousing
- Ontology Based Data Management
- Process and Workflow Management
- Service Modeling
- Service Synthesis and Composition

Members: CATARCI Tiziana, CIMA Gianluca, CONSOLE Marco, DE GIACOMO Giuseppe, LEMBO Domenico, LENZERINI Maurizio (leader), LEOTTA Francesco, MECELLA Massimo, PATRIZI Fabio, POGGI Antonella, ROSATI Riccardo and SCAFOGLIERI Federico Maria

Post Docs: CROCE Federico

PhD students: ANDOLFI Luca, DELFINO Roberto Maria, MARCONI Lorenzo, NAMICI Manuel and VALENTINI Riccardo

Our interest in Data Management dates back to the 80's, when the main research topics addressed by our group were conceptual modeling and schema integration. Starting in the late 90's, it evolved into Information Integration and Data Exchange. Information integration is the problem of combining the data residing at different heterogeneous sources, and providing a virtual unified view of these data, called global schema, which can be queried by the users. Data Exchange focuses instead on the problem of materializing the global schema according to the data retrieved from the sources. Ontology-based data management (OBDM) is a promising direction for addressing the above challenges. The key idea of OBDM is to resort to a three-level architecture, constituted by the ontology, the sources, and the mapping between the two, where the ontology is a formal description of the domain of interest, and is the heart of the whole system. With this approach, the integrated view that the system provides to information consumers is not merely a data structure accommodating the various data at the sources, but a semantically rich description of the relevant concepts in the domain of interest, as well as the relationships between such concepts. Other Data Management topics related to Information Integration are also investigated, including View-based Query Processing, Data Warehousing, Data Quality, and Data Cleaning.

Our research interests include several aspects of Service-Oriented Computing, and its relationship with Data Management. Services in our context are autonomous, platform-independent computational elements that can be described, published, discovered, orchestrated and programmed for the purpose of developing distributed interoperable applications. We are particularly interested in service modeling and automatic service composition. In this area, we proposed what in the community is now known as the "Roman model", and contributing to one of the first solutions to automated service composition. Since its introduction, the Roman model has been studied by several research groups worldwide, and is one of the key references in the formal approaches to automated service composition. We have also studied Service Synthesis, as well as Process and Workflow Management, with a

special focus on principles and techniques for modeling the interaction between processes and data.

Data and Service Integration is considered one of the main challenges that Information Technology (IT) currently faces. It is highly relevant in classical IT applications, such as enterprise information management and data warehousing, as well as in scenarios like scientific computing, e-government, and web data management. Our long-term goal is to lay the foundations of a new generation of information integration and service composition systems, whose main characteristics are:

1. posing the semantics of the application domain at the center of the scene,
2. combining the management of data with the management of the processes and ser- vices using such data in the organization, and
3. shifting the role of the conceptual model from a design-time to a run-time artifact.

In our vision, the functionalities provided by the system include answering queries posed in terms of the conceptual model by suitably accessing the source data, performing updates over the conceptual models by invoking the appropriate updates on the sources, and realizing complex goals expressed by the client by automatically composing available services. The basic idea for realizing this goal is to combine principles, methods and techniques from different areas, namely, Data Management, Service-Oriented Computing, Knowledge Representation and Reasoning, and Formal Methods.

In 2022, members of the research group have been invited to organize various events, and to deliver keynote speeches at various conferences and workshops.

Publications

Journal papers

Cima G., Console M., Lenzerini M., Poggi A. "A review of data abstraction". In: *Frontiers In Artificial Intelligence*, (volume: 6) (2023). DOI: 10.3389/frai.2023.1085754

Maggi Fabrizio Maria, Marrella Andrea, Patrizi Fabio, Skydanienko Vasyl "Data-Aware Declarative Process Mining with SAT". In: *Acm Transactions On Intelligent Systems And Technology*, (2023). DOI: 10.1145/3600106

Alman A., Maggi F. M., Montali M., Patrizi F., Rivkin A. "Monitoring hybrid process specifications with conflict management: An automata-theoretic approach". In: *Artificial Intelligence In Medicine*, (volume: 139) (2023). DOI: 10.1016/j.artmed.2023.102512

Agostinelli Simone, Chiariello Francesco, Maggi Fabrizio Maria, Marrella Andrea, Patrizi Fabio "Process mining meets model learning: Discovering deterministic finite state automata from event logs for business process analysis". In: *Information Systems*, (volume: 114) (2023). DOI: 10.1016/j.is.2023.102180

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Bienvenu M., Cima G., Gutierrez-basulto V., Ibanez-garcia Y. "Combining Global and Local Merges in Logic-based Entity Resolution". In: *Proceedings Of The 20th International Conference On Principles Of Knowledge Representation And Reasoning, Kr 2023*, (2023), pp. 742 - 746.

Bonatti Piero, Cima Gianluca, Lembo Domenico, Marconi Lorenzo, Rosati Riccardo, Sauro Luigi, Fabio Savo Domenico "Dynamic Controlled Query Evaluation over DL-Lite

Ontologies (Extended Abstract)". In: *Proceedings Of The 36th International Workshop On Description Logics (dl 2023)*, (2023).

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Fernandez-gil Oliver, Patrizi Fabio, Perelli Giuseppe, Turhan Anni-yasmin "Optimal Alignment of Temporal Knowledge Bases". In: *European Conference On Artificial Intelligence*, (2023), pp. 708 - 715. DOI: 10.3233/FAIA230335

Bienvenu M., Cima G., Gutierrez-basulto V. "REPLACE: A Logical Framework for Combining Collective Entity Resolution and Repairing". In: *Thirty-second International Joint Conference On Artificial Intelligence, Ijcai 2023*, (2023), pp. 3132 - 3139.

Bienvenu M., Cima G., Gutierrez-basulto V. "On Combining Collective Entity Resolution and Repairing (Extended Abstract)". In: *Ceur Workshop Proceedings*, (volume: 3495) (2023), pp. 93 - 95.

3.2.8 Distributed Systems

Research lines:

- Distributed Systems Interoperability
- Event-based Systems
- Fog Computing
- Resource Sharing Systems
- Secure and robust distributed systems
- Smart Environments
- Streaming
- Theoretical Aspects of DLTs

Members: BERALDI Roberto, BONOMI Silvia (leader), DI LUNA Giuseppe Antonio, PROIETTI MATTIA Gabriele, QUERZONI Leonardo and FARINA Giovanni

Affiliated: BALDONI Roberto *(Former)* and CICIANI Bruno *(Former)*

PhD students: SCANU Fabio

The Distributed Systems group has developed, in the last fifteen years, a solid worldwide reputation in the context of theory and practice of distributed, pervasive and p2p computing, middleware platforms, data processing, and information systems infrastructures. On these topics, the group has created strong relationships with the most influential research groups in the world. We developed several theories and practical experiences in various topics including checkpointing, causal and total ordering theory, distributed replication, group communication, distributed agreement, publish subscribe systems, dynamic systems, byzantine fault tolerance, distributed stream processing, etc.

The distributed systems group has participated and successfully coordinated several important EU projects in the context of e-government, security and dependability of large scale systems, and protection of critical infrastructures. It has developed remarkable connections with the major Italian ICT industries and Public Administrations for creating innovative solutions and prototypes transferring the latest results from research area into practice.

Current research areas include:

Byzantine fault-tolerant algorithms: in the past few years the group has proposed several solutions in the area of BFT focussing, in particular, on algorithms for basic distributed abstractions in both static and dynamic settings and algorithms for robust lattice agreement algorithms. In this context, the group is also investigating solutions able to deal with the so called Mobile Byzantine Failure model.

Distributed stream processing systems: since 2003 the group has regularly proposed novel solutions for improving the efficiency of distributed stream processing systems. In particular, we focussed our efforts on designing solutions to dynamically adapt the system

runtime to changes in the input load distribution to tackle different goals (e.g. latency reduction, throughout maximization, efficient resource usage, etc.)

Dynamic networks and population protocols: The group has a keen interest in the study of dynamic networks, especially the one composed by anonymous processes. In this area, it has designed the first known terminating counting algorithms for rooted interval-connected networks, bootstrapping the research in the field. Regarding, population protocols the group has been the first to investigate computability under faulty interactions increasing the understanding of fault-tolerance for population protocols. The group also provided contribution to the analysis of theoretical aspect of distributed systems affected by continuous churn i.e., the phenomenon of continuously changing the set of processes participating in to the distributed system.

Mobile agents and robots: The DS group has strong expertise in the field of mobile agents (autonomous entities inhabiting a graph) and mobile robots (autonomous entities inhabiting an euclidean space). Regarding mobile agents, it has been the first to investigate, with a distributed perspective, the problems of exploration, gathering, patrolling, and black hole search on dynamic interval connected graphs. While in the field of robots it has been the first to study the computational power of luminous robots in the obstructive model, and it has given general contributions in understanding the computational power of oblivious robots in the setting of restricted visibility.

DLT and Blockchain: in the fast few years the group started to investigate the theoretical foundations of Blockchains and (more in general) of DLT and how to efficiently take advantage of such technologies to support applications behind cryptocurrencies.

Fog and Edge Computing: The DS group also has experience in designing distributed, cooperative, and decentralized algorithms that target the problems of load balancing and scheduling problems in the Edge and Fog Computing environments. With the former, we intend to optimize the load among all the nodes involved in the system to avoid saturation and consequently increase the number of successfully served tasks and minimize the latency, while in the latter, we deal with tasks that have specific deadlines that they necessarily need to meet. We have expertise in mathematical modeling (probabilistic models, linear optimization, and discrete/continuous time systems) of the problem and modern technologies like Docker and Kubernetes. Moreover, we also rely on Reinforcement Learning to design adaptive and resilient strategies that cope with unpredictable changes in the environment in which the algorithm runs. In general, our main objective is to start from the problem analysis, then model the system and the solution, and finally implement a working approach both in simulation and on real and pseudo-real environments, such as clusters of Raspberry Pis. For this reason, the group also developed an open-source framework called P2PFaaS (https://p2p-faas.gitlab.io) which allows the implementation of cooperative and decentralized scheduling and load-balancing algorithms on Fog and Edge nodes which are Docker-enabled.

The Distributed Systems group is also strongly involved in the activities of the Research Center of Cyber Intelligence and Information Security (CIS). CIS does leadership research

in the context of cyber security, information assurance, critical information infrastructure protection, trend prediction, malware analysis, open-source intelligence, cyber physical systems and smart complex systems. Advanced capabilities in cyber intelligence will be indeed essential in the next years due to the pervasiveness of cloud, social computing and mobility technologies, that lower the control that organizations and governments have over systems, infrastructure and data. CIS aims at designing better information security methodologies, threat profiles and at elaborating defense strategies taking into account the economic and legal impact in a unique framework. Research results are applied to real world contexts such as cyberwarfare, fraud detection, stock market stability, detection of tax evasion, monitoring of mission-critical systems, early warning systems and smart environments.

Publications

Journal papers

Proietti Mattia Gabriele, Pietrabissa Antonio, Beraldi Roberto "A Load Balancing Algorithm for Equalising Latency across Fog or Edge Computing Nodes". In: *Ieee Transactions On Services Computing*, (2023), pp. 1 - 12. DOI: 10.1109/TSC.2023.3265883

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3.2.9 Human-Computer Interaction

Research lines:

- Automated Personalization and Adaptation in Web-based Learning
- Game-based Technology-Enhanced Learning
- Information Visualization
- Usability Engineering and Accessibility
- User Interfaces
- Visual control
- Web-based Social Collaborative Learning

Members: AGOSTINELLI Simone, CATARCI Tiziana (leader), LENTI Simone, LEOTTA Francesco, MARRELLA Andrea, MECELLA Massimo, SANTUCCI Giuseppe, TEMPERINI Marco and ANGELINI Marco

Post Docs: MONTI Flavia and SAPIO Francesco

PhD students: ACITELLI Giacomo, BENVENUTI Dario, DE LUZI Francesca, FERRO Lauren, MACRI Mattia, MATHEW Jerin George, MORVILLO Alberto, PALLESCHI Alessia and VENERUSO Silvestro V.

Human-Computer interaction (HCI) is the study of the interaction between people (users) and computers. Such an interaction traditionally occurs at the user interface, but its effectiveness is strongly related with the design of the entire interactive system, referring in particular to the way in which it supports the user in achieving her/his goals and executing her/his tasks. Indeed, an important facet of HCI is the securing of the interactive system usability. The research group started working on HCI topics during the late ’80s, while developing a visual interface for databases. This pioneering work can be regarded as one of the first and most significant examples of deep analysis and formalization of the interaction between the user and the database, which takes into consideration both usability issues and language related aspects.
Following these lines, the group developed another relevant research topic, namely the definition of adequate visual representations of the databases, in terms of both schema and instances. Note that using a consistent visual representation to depict the information of interest is crucial in order for the user to correctly grasp the database in- formation content. Related with visual representation is information visualization, i.e. the use of computer-based, visual, interactive representations of information with the purpose of making sense out of data, acquire knowledge, discover new information, and effectively present the result.

In the last years we focused on clutter reduction for information visualization analyzing the visual issues associated with the use of density maps focusing on the correct assignment of visual variable values to a data domain, taking into account its frequency distributions. Other HCI topics are also investigated, including the study of specific usability, accessibility, and adaptivity methodological aspects, the interaction with different realms, e.g. digital libraries, cultural artifacts, mobile and ubiquitous systems, technology-enhanced learning environments.

Designing interactive systems that could be effectively, efficiently and with satisfaction used by people exhibiting different characteristics, needs, preferences and abilities is getting more and more important in Information Technology research and development, as it is clearly demonstrated by the growing importance of the user role in research projects as well as in public administration developments, by the introduction in several Laws of precise usability and accessibility requirements for governmental information systems, by the continuous increase of funding for HCI-related research at EU and inter- national level.

We have been among the pioneers of the research in this field in Europe, in particular in the effort of giving formal basis to the definition of interaction while considering human-related, perceptual aspects. We are still continuing in this direction, in particular by working on a machine-interpretable and machine-learnable model of user task that will be the basis for a novel task-oriented interaction model, to be tested in personal in- formation environments. Furthermore, innovative interaction styles, e.g. brain-computer interfaces, ubiquitous and sensor-based environments, extreme visualizations, are under study, as well as novel design methodologies, advancing traditional user-centered design both with the injection of agile concepts and directly encompassing accessibility aspects.

Publications

Journal papers

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Conference proceedings

Catarci Tiziana, Polidori Barbara, Raffini Daniel, Velardi Paola "A Greed(y) Training Strategy to Attract High School Girls to Undertake Studies in ICT". In: *Hci International 2023 Conference, 23-28 July, Copenhagen, Denmark, Lecture Notes In Computer Science, 2023*, (2023).

Russo Michele, Giugliano Alessandra Marina, Flenghi Giulia, Carnevali Laura, Martone Maria, Marrella Andrea, Sapio Francesco "Augmented Geometry in university education". In: *Inted2023 Proceedings*, (2023), pp. 1787 - 1796. DOI: 10.21125/inted.2023.0506

3.2.10 Natural language processing

Research lines:

- Multilinguality
- Natural Language Processing
- Natural Language Understanding

Members: BARBA Edoardo and NAVIGLI Roberto (leader)

PhD students: BEJGU Andrei Stefan, BONOMO Tommaso, HUGUET CABOT Pere-Lluis, MARTINELLI Giuliano, MOLFESE Francesco Maria, ORLANDO Riccardo, PERRELLA Stefano and PROIETTI Lorenzo

The Sapienza Natural Language Processing Group (Sapienza NLP), led by prof. Roberto Navigli, includes a large team of Ph.D. students and researchers which are part of the Computer, Control and Management Engineering Department and the Computer Science Department of the Sapienza University of Rome. The group aims at devising and developing innovative approaches to multilingual Natural Language Understanding and Generation. Sapienza NLP pursues a vision focused on integrating explicit, symbolic information with cutting-edge deep learning. The group's work is financed by several sources of funding, including ERC grants, other EU and national projects, and the Babelscape, a successful spin-off company.

Publications

Journal papers

Navigli R., Conia S., Ross B. "Biases in Large Language Models: Origins, Inventory, and Discussion". In: *Acm Journal Of Data And Information Quality*, (volume: 15) (2023), pp. 1 - 21. DOI: 10.1145/3597307

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Purificato Antonio, Navigli Roberto "APatt at SemEval-2023 Task 3: The Sapienza NLP System for Ensemble-based Multilingual Propaganda Detection". In: *Proceedings Of The The 17th International Workshop On Semantic Evaluation (semeval-2023)*, (2023).

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Scirè Alessandro, Conia Simone, Ciciliano Simone, Navigli Roberto "Echoes from Alexandria: A Large Resource for Multilingual Book Summarization". In: *Findings Of The Association For Computational Linguistics: Acl 2023*, (2023).

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3.2.11 Processes, Services and Software Engineering

Research lines:

- Internet of Things
- Process and Workflow Management
- Reasoning about Actions and Planning
- Service Synthesis and Composition

Members: AGOSTINELLI Simone, LEOTTA Francesco, MARRELLA Andrea (leader) and MECELLA Massimo (leader)

PhD students: ACITELLI Giacomo, BENVENUTI Dario, DE LUZI Francesca, MACRI Mattia, MARINACCI Matteo, MATHEW Jerin George, MONTI Flavia and VENERUSO Silvestro V.

Post Docs: MONTI Flavia

Gruppo di ricerca Processes, Services and Software Engineering

Publications

Journal papers

Dumas Marlon, Fournier Fabiana, Limonad Lior, Marrella Andrea, Montali Marco, Rehse Jana-rebecca, Accorsi Rafael, Calvanese Diego, De Giacomo Giuseppe, Fahland Dirk, Gal Avigdor, Rosa Marcello La, Völzer Hagen, Weber Ingo "AI-Augmented Business Process Management Systems: A Research Manifesto". In: *Acm Transactions On Management Information Systems*, (volume: 14) (2023). DOI: 10.1145/3576047

3.2.12 Theory of Deep Learning

Research lines:

- Neural Networks and Support Vector Machines

Members: AMERINI Irene, BACCINI Federica, BECCHETTI Luca, SICILIANO Federico, SILVESTRI Fabrizio (leader) and TRAPPOLINI Giovanni

PhD students: BACCIU Andrea, BETELLO Filippo, CASO Francesco, CASSARA Giulia, CUCONASU Florin, D'ERASMO Giulio, DI FRANCESCO Andrea Giuseppe, LENTI Jacopo, PIKTUS Aleksandra , PURIFICATO Antonio and WANI Farooq Ahmad

Post Docs: BUCARELLI Maria Sofia, CAMPAGNANO Cesare and RUSCIO Valeria

The RSTLess research group is a dynamic and innovative team of researchers from Sapienza University of Rome, led by Professor Fabrizio Silvestri.

Our focus is on the cutting-edge fields of Deep Learning, Information Retrieval, Graph Neural Networks, and Natural Language Processing, with a special emphasis on Robustness, Safety, and Transparency.
The team's mission is to push the boundaries of these areas and deliver cutting-edge solutions that have a real impact on society, while ensuring the robustness, safety, and transparency of our algorithms.
Our team is made up of experts in the field, and we are constantly collaborating with other researchers, academic institutions, and industry partners to advance our understanding of these areas and to develop new, innovative solutions that meet the highest standards of robustness, safety, and transparency.

Publications

Journal papers

Maiano Luca, Montuschi Antonio, Caserio Marta, Ferri Egon, Kieffer Federico, Germanò Chiara, Baiocco Lorenzo, Ricciardi Celsi Lorenzo, Amerini Irene, Anagnostopoulos Aristidis "A deep-learning–based antifraud system for car-insurance claims". In: *Expert Systems With Applications*, (volume: 231) (2023). DOI: 10.1016/j.eswa.2023.120644

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Papa Lorenzo, Proietti Mattia Gabriele, Russo Paolo, Amerini Irene, Beraldi Roberto "Lightweight and Energy-Aware Monocular Depth Estimation Models for IoT Embedded

Devices: Challenges and Performances in Terrestrial and Underwater Scenarios". In: *Sensors*, (volume: 23) (2023). DOI: 10.3390/s23042223

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Cristofaro A., Cappellini G., Staffetti E., Trappolini G., Vendittelli M. "Adaptive Estimation of the Pennes' Bio-Heat Equation - I: Observer Design". In: *2023 Ieee 62nd Conference On Decision And Control (cdc)*, (2023), pp. - 1936. DOI: 10.1109/CDC49753.2023.10383905

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Bucarelli Maria Sofia, Cassano Lucas, Siciliano Federico, Mantrach Amin, Silvestri Fabrizio "Leveraging Inter-Rater Agreement for Classification in the Presence of Noisy Labels". In: *2023 Ieee/cvf Conference On Computer Vision And Pattern Recognition (cvpr)*, (2023), pp. 3439 - 3448. DOI: 10.1109/CVPR52729.2023.00335

Trappolini G., Santilli A., Rodola E., Halevy A., Silvestri F. "Multimodal Neural Databases". In: *Proceedings Of The 46th International Acm Sigir Conference On Research And Development In Information Retrieval*, (2023), pp. 2619 - 2628. DOI: 10.1145/3539618.3591930

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Tolomei Gabriele, Campagnano Cesare, Silvestri Fabrizio, Trappolini Giovanni "Prompt-to-OS (P2OS): Revolutionizing Operating Systems and Human-Computer Interaction with Integrated AI Generative Models". In: *Proceedings Of The 2023 Ieee 5th International*

Conference On Cognitive Machine Intelligence (cogmi), (2023), pp. 128 - 134.
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3.3 Economics and Management Engineering

3.3.1 Industrial Organization and Management

Research lines:

- Economics and Management of Education and Research
- Economics and regulation of network industries
- Operations Management
- Productivity and efficiency analysis
- Project Management
- R&D, Innovation, and public policies
- Renewable Energy Sources and Environmental Policies
- Strategic Management
- Sustainability and environmental management

Members: ANNARELLI Alessandro, AVENALI Alessandro, CATALANO Giuseppe, CONTI Chiara, D'ADAMO Idiano, D'ALFONSO Tiziana, DARAIO Cinzia, DI LEO Simone, DI PILLO Francesca, FRACCASCIA Luca, GIAGNORIO Mirko, GREGORI Martina, GROSSO Chiara, MARZANO Riccardo, MATTEUCCI Giorgio, NASTASI Alberto (leader), NONINO Fabio, OROPALLO Eugenio and REVERBERI Pierfrancesco

Post Docs: QUAGLIA Giammarco and VONA Luigi

PhD students: DE SANTIS Daniele, MOLLICA Melissa, PETITTI Federico and QUAGLIERI Luca

The research activity of the group, which includes general issues in industrial economics, public policy, and management, focuses on the following research lines:

1. Economics and regulation of network industries
2. Operations management
3. Productivity and efficiency analysis
4. Project Management
5. R&D, Innovation, and public policies
6. Strategic Management
7. Sustainability and environmental management

For each research line, the main research topics are highlighted as follows:

1. **Economics and regulation of network industries**
    - Competition, regulation, investment incentives, and industrial policy in network industries, with a focus on air transport, rail transport, local public transport and utilities
    - Game-theoretic models to assess the welfare effects of access conditions to enduring economic bottlenecks, depending on the vertical industry structure, with a focus on telecommunications and transportation
    - Allocation and pricing of scarce network resources
    - Sharing economy and peer-to-peer platforms

- Standard cost assessment of public transport
- Efficiency and effectiveness analysis regarding local public transport
- Strategic and business aspects of rolling stock management for public transport (introduction of alternative fuel technologies)
- Changes on mobility-framework towards more sustainable solutions
- Economic benchmarking of transport modes
- Competition in passenger transportation markets
- Dynamic congestion

2. **Operations management**
   - Auction mechanism for valuable economic resources allocation with complementarity/substitutability relationships, cost analysis, top-down and bottom-up cost models
   - Operational aspects of environmental sustainability practices at both the company and the network level

3. **Productivity and efficiency analysis**
   - Theoretical, methodological, and empirical models for the assessment of efficiency, effectiveness and impact.
   - Advanced nonparametric and robust methods for the assessment of public and private services
   - Performance evaluation of academy departments and heterogeneity analysis of European higher education institutions
   - Investigations on the economics, management, and modeling of scientific research and higher education

4. **Project Management**
   - Business opportunities and social welfare resulting from an effective integration of sustainability principles inside project management practices both at corporate and project manager individual level
   - Managerial implications of project management practices and organizational aspects (e.g., informal social networks, individuals' and small groups' behavior, culture) with interest in specific emergent contexts such as industry 4.0, circular economy, and cyber security

5. **R&D, Innovation, and public policies**
   - Theoretical and empirical models applied to the analysis of the drivers of innovative performance, with a special interest in externalities, public policies' impact on R&D strategies, and welfare effects
   - Relationship between R&D investment decisions and environmental policies focusing on their role in spurring innovation
   - Empirical research on innovation and diffusion of clean technologies within Europe investigating the impact of EU support
   - Analysis of the interplay among competition, regulation, and the incentives to invest in product quality, with a focus on research-intensive industries

- Economic aspects of privacy regulation, in particular on the role of consumers' data in innovation processes

6. **Strategic Management**
   - Ownership and corporate governance mechanisms and their interaction with the institutional variety as drivers of firm's internationalization strategies

7. **Sustainability and environmental management**
   - Operational and business aspects of circular economy strategies, e.g., industrial symbiosis, renewable energy production, waste management, bioeconomy, industry 4.0
   - Circular business models
   - Operational and managerial aspects linked to relevant strategic transitions of companies, i.e., the servitization of business and the digital transformation of business
   - Consumer behavior towards the adoption of green innovations
   - Antecedents, outcomes, and success factors of the integration of environmental sustainability within firm strategies and innovation development
   - Effects of trade liberalization in environmental goods as a means of helping developed and developing countries alike deal with environmental problems

Finally, the group has established scientific collaborations with national and international public institutions and universities. It is part of the European Network of Indicators Designers (ENID) and of the observatory on Local Public Transport of the Ministry of Infrastructures and Transport (MIT). It has implemented and implements collaborations with several institutions, e.g.,: (1) the National Agency for University and Scientific Research Evaluation (ANVUR), the Ministry of Education, Universities, and Research (MIUR) concerning the evaluation of the impact of public policies for higher education and scientific research; the Ministry of infrastructures and Transport and the European Commission on the themes of the standard cost of local public transport; (3) ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) on the themes related to industrial symbiosis.

Publications

Journal papers

D'adamo I., Ippolito N. M., Shalchian H., Innocenzi V., Ferella F., Veglio F. "A feasibility study for a circular approach in oil refining: Metals recovery from hydrodesulphurization catalysts". In: *Sustainable Materials And Technologies*, (volume: 36) (2023). DOI: 10.1016/j.susmat.2023.e00634

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Basile Davide, D'adamo Idiano, Goretti Valerio, Rosa Paolo "Digitalizing Circular Economy through Blockchains: The Blockchain Circular Economy Index". In: *Journal Of Industrial And Production Engineering*, (2023), pp. 1 - 13. DOI: 10.1080/21681015.2023.2173317

Dwivedi Ashish, Sassanelli Claudio, Agrawal Dindayal, Abdul Moktadir Md., D'adamo Idiano "Drivers to mitigate climate change in context of manufacturing industry: An emerging economy study". In: *Business Strategy And The Environment*, (2023). DOI: 10.1002/bse.3376

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3.4 Operations Research

3.4.1 Combinatorial Optimization

Research lines:

- Computational Biology and Bioinformatics
- Data Mining and Classification
- Graph theory and Optimization
- Information Reconstruction
- Polyhedral Combinatorics
- Portfolio Optimization
- Robust Optimization
- Satisfiability in Propositional Logic
- Scheduling and Job-shop Scheduling
- Telecommunication Network Design

Members: BRUNI Renato, FURINI Fabio, SASSANO Antonio (leader) and MELONI Carlo

Combinatorial Optimization is a thriving field at the forefront of discrete mathematics and theoretical computer science. Its main focus is the efficient discovery of specific data structures and optimal set of objects into a finite (but large) collection of feasible solutions. Graph Theory, Integer Programming and Polyhedral Combinatorics are the key methodological tools in this area.The activity of the Combinatorial Optimization Group at DIAG dates back to the early '90s and has been focused both on the theoretical properties of combinatorial structures and the use of sophisticated algorithmic tools to solve real-life problems. In particular, major research has been carried out on the following subjects: polyhedral properties of set covering, stable set and p-median problems; perfect graph theory, exact and heuristic algorithms for stable set and set covering; algorithms for coloring and frequency assignment problems; decomposition algorithms and reformulations for wireless network design problem; fixed network design and survival network design; algorithms for job-shop scheduling and railway traffic management; algorithms for satisfiability of logic formulae, algorithms for information reconstruction in large datasets, algorithms for classification based on propositional logic, algorithms for inconsistency selections, algorithms for the optimal and robust determination of control parameters of vehicles or spacecrafts.The group is currently cooperating with the Italian Ministry of Economic Development, the Italian Authority of Telecommunications (AGCOM), Fondazione "Ugo Bordoni" and Istituto Nazionale di Statistica (ISTAT). In the last 10 years, the group has been involved in a large number of national and international projects and has developed methods and algorithms aimed at the optimal design of broadcasting networks. The scientific leadership gained in this field has motivated a stable cooperation with the Italian Authority for Telecommunication and the decisive contribution of the group to the design of the national (analog and digital) TV and radio plans. The current key members of the group have published more than 100 journal papers, several book chapters, and two books. Moreover they are or have been editors of some of the main journals in the field of Operations Research and Optimization. In addition to further development of on-going research project, our future activities involve the study of optimization algorithms to rescue or prevent financial crises and for portfolio management;

algorithms for clustering and imputation of Educational Institutions in the study of educational systems; algorithms for weighted matching and stable set problems; polyhedral properties of the stable set polyhedron and of interval and staircase matrices; optimization techniques for classification problems in machine learning; purely combinatorial approaches to wireless network design; railway traffic control and optimization on single-track networks.

Publications

Journal papers

Martinovic J., Strasdat N., Valerio De Carvalho J., Furini F. "A combinatorial flow-based formulation for temporal bin packing problems". In: *European Journal Of Operational Research*, (volume: 307) (2023), pp. 554 - 574. DOI: 10.1016/j.ejor.2022.10.012

Avella Pasquale, Calamita Alice, Palagi Laura "A compact formulation for the base station deployment problem in wireless networks". In: *Networks*, (2023). DOI: 10.1002/net.22146

San Segundo P., Furini F., Alvarez D., Pardalos P. M. "CliSAT: A new exact algorithm for hard maximum clique problems". In: *European Journal Of Operational Research*, (volume: 307) (2023), pp. 1008 - 1025. DOI: 10.1016/j.ejor.2022.10.028

Bruni R, Bianchi G, Papa P "Hyperparameter Black-Box Optimization to Improve the Automatic Classification of Support Tickets". In: *Algorithms*, (volume: 16) (2023). DOI: 10.3390/a16010046

3.4.2 Continuous Optimization

Research lines:

- Big Data Optimization
- Bilevel Optimization
- Derivative Free Methods
- Engineering Design Optimization
- Game Engineering
- Global Optimization
- Mixed Integer Nonlinear Programming
- Neural Networks and Support Vector Machines
- Nonlinear Optimization
- Parallel and distributed optimization methods
- Resource allocation in communication networks
- Semidefinite Programming
- Simulation–based optimization
- Variational Inequalities

Members: CROELLA Anna Livia, DE SANTIS Alberto, DOSE Valerio, FACCHINEI Francisco (leader), LIUZZI Giampaolo, LUCIDI Stefano, PALAGI Laura, PICCIALLI Veronica, ROMA Massimo, SAGRATELLA Simone, SALZO Saverio, SCIANDRONE Marco, SUDOSO Antonio Maria and DE SANTIS Marianna

PhD students: BATTISTA Federico *(Former)*, BORESTA Marco *(Former)*, CALAMITA Alice, COPPOLA Corrado, D'AVINO Arcangelo, D'ONOFRIO Federico, GIANCOLA Francesca, MARIOSA Raffaele, MEROLLA Davide, PATRIA Daniele, PIERMARINI Christian, PINTO Diego Maria *(Former)*, PRIORI Gianluca, SASSO Valerio, SCARPONI Giulio and TRONCI Edoardo Maria *(Former)*

Post Docs: MONACI Marta and BRILLI Andrea

Research in continuous optimization has been active at DIAG since its foundation. Early research was essentially devoted to the theory of exact penalization and to the development of algorithms for the solution of constrained nonlinear programming problems through unconstrained techniques. Significant early contributions were also given in the field of unconstrained optimization, with the introduction of non monotone line searches, non monotone globalization strategies and convergent derivative-free line search techniques. The Continuous Optimization group later expanded into an active and highly valued optimization research team with a wide range of interests.
The following areas are object of current research.
• Exact penalty and augmented Lagrangian methods, still constituting the founding block of many optimization methods and a springboard for many of the studies of the group.
• Non-monotone methods and decomposition techniques for the solution of difficult large-scale nonlinear optimization problems and nonlinear equations.
• Preconditioning Newton-Krylov and Nonlinear Conjugate Gradient methods in nonconvex large scale optimization, which is an important tool for efficiently solving large difficult problems.

• Derivative-free algorithms, of special interest in many engineering applications where even the calculation of function values is problematic and very time-consuming.
• Global optimization, which is an essential tool for solving problems where local non-global solutions may be meaningless.
• Semidefinite programming, which plays an essential role in the development of efficient algorithms for solving relaxations of non-convex and integer problems.
• Finite dimensional variational inequalities and complementarity problems, which often arise in modeling a wide array of real-world problems where competition is involved.
• Generalized Nash equilibrium problems, which are emerging as a winning way of looking at several classical and non-classical engineering problems.
• Training methods for neural networks and support vector machines, for constructing surrogate models of complex systems from sparse data through learning techniques.
• Mixed Integer Nonlinear Programming (MINLP) problems that combine combinatorial aspects with nonlinearities.
The Continuous Optimization group interacts intensively with many other research groups, both in the academic and industrial world, in an ongoing cross-fertilization process. This process led to several innovative applications in such different fields as:
• Design of electro-mechanic devices.
• Development of electromagnetic diagnostic equipments.
• Power allocation in TLC.
• Shape optimization in ship design.
• Multiobjective optimization of nanoelectronic devices.
• Optimization of ship itineraries for a cruise fleet.
• Sales forecasting in retail stores.

Publications

Journal papers

Cesarone F, Lampariello L, Merolla D, Ricci Jm, Sagratella S, Sasso Vg "A bilevel approach to ESG multi-portfolio selection". In: *Computational Management Science*, (volume: 20) (2023). DOI: 10.1007/s10287-023-00458-y

Gaudioso Manlio, Liuzzi Giampaolo, Lucidi Stefano "A clustering heuristic to improve a derivative-free algorithm for nonsmooth optimization". In: *Optimization Letters*, (2023). DOI: 10.1007/s11590-023-02042-4

Raparelli Valeria, Romiti Giulio Francesco, Di Teodoro Giulia, Seccia Ruggiero, Tanzilli Gaetano, Viceconte Nicola, Marrapodi Ramona, Flego Davide, Corica Bernadette, Cangemi Roberto, Pilote Louise, Basili Stefania, Proietti Marco, Palagi Laura, Stefanini Lucia "A machine-learning based bio-psycho-social model for the prediction of non-obstructive and obstructive coronary artery disease". In: *Clinical Research In Cardiology*, (2023). DOI: 10.1007/s00392-023-02193-5

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Bettiol E., Buchheim C., De Santis M., Rinaldi F. "An oracle-based framework for robust combinatorial optimization". In: *Journal Of Global Optimization*, (2023). DOI: 10.1007/s10898-023-01271-2

Grazzi Riccardo, Pontil Massimiliano, Salzo Saverio "Bilevel Optimization with a Lower-level Contraction: Optimal Sample Complexity without Warm-Start". In: *Journal Of Machine Learning Research*, (volume: 24) (2023), pp. 1 - 37.

Rossetti Barbara, Incardona Francesca, Di Teodoro Giulia, Mommo Chiara, Saladini Francesco, Kaiser Rolf, Sönnerborg Anders, Lengauer Thomas, Zazzi Maurizio "Cohort Profile: A European Multidisciplinary Network for the Fight against HIV Drug Resistance (EuResist Network)". In: *Tropical Medicine And Infectious Disease*, (volume: 8) (2023). DOI: 10.3390/tropicalmed8050243

Traoré Cheik, Salzo Saverio, Villa Silvia "Convergence of an asynchronous block-coordinate forward-backward algorithm for convex composite optimization". In: *Computational Optimization And Applications*, (2023). DOI: 10.1007/s10589-023-00489-w

Addis Bernardetta, Castel Christophe, Macali Amalia, Misener Ruth, Piccialli Veronica "Data augmentation driven by optimization for membrane separation process synthesis". In: *Computers & Chemical Engineering*, (2023). DOI: 10.1016/j.compchemeng.2023.108342

Piccialli Veronica, Sudoso Antonio M. "Global optimization for cardinality-constrained minimum sum-of-squares clustering via semidefinite programming". In: *Mathematical Programming*, (2023). DOI: 10.1007/s10107-023-02021-8

Cristofari A., De Santis M., Lucidi S., Rothwell J., Casula E. P., Rocchi L. "Machine Learning-Based Classification to Disentangle EEG Responses to TMS and Auditory Input". In: *Brain Sciences*, (volume: 13) (2023). DOI: 10.3390/brainsci13060866

D'onofrio Federico, Monaci Marta, Palagi Laura "Optimization-based approaches for learning Optimal Classification Trees". In: *Ifors News*, (volume: 18) (2023), pp. 5 - 7.

Piccialli Veronica, Romero Morales Dolores, Salvatore Cecilia "Supervised feature compression based on counterfactual analysis". In: *European Journal Of Operational Research*, (2023). DOI: 10.1016/j.ejor.2023.11.019

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Di Teodoro Giulia, Monaci Marta, Palagi Laura "Unboxing Tree Ensembles for interpretability: a hierarchical visualization tool and a multivariate optimal re-built tree". In: , (2023). DOI: 10.48550/arXiv.2302.07580

3.5 Systems and Control Engineering

3.5.1 Networked Systems

Research lines:

- Control Applications
- Control of Networks
- Control under Communication Constraints
- Modeling, Filtering and Optimal Control of Communication Networks
- Reinforcement Learning
- Wireless and Sensor Networks

Members: DE SANTIS Emanuele, DELLI PRISCOLI Francesco, DI GIORGIO Alessandro (leader), GIUSEPPI Alessandro, LIBERATI Francesco and PIETRABISSA Antonio (leader)

PhD students: ATANASIOUS Mohab , BALDISSERI Federico, BECCHETTI Valentina, DI PAOLA Antonio, DONSANTE Manuel, GENTILE Simone, IMRAN Muhammad, MAIANI Arturo and TANTUCCI Andrea

Post Docs: MENEGATTI Danilo and WRONA Andrea

The Networked Systems research group, led by Proff. Alessandro Di Giorgio and Antonio Pietrabissa, aims at developing control methodologies in the context of networked systems. Besides classical control methods, such as model predictive control, optimal control and robust control, distributed non-cooperative control methods are being developed on the ground of mean-field game theory as well as learning methodologies such as reinforcement learning and deep reinforcement learning. Application areas of interest are communication networks, energy distribution networks, cyber-physical security in interconnected systems, bioengineering (e.g., brain connectivity).

The Networked Systems group members cooperate with researchers from national and international academia and industries. The members of the group are still cooperating with Alberto Isidori (professor emeritus), founder member of the group. Among other collaborations, currently the group's members are working with ETRI (Electronics and Telecommunications Research Institute), which is the most important research institute in South Korea, CEA (Commissariat à l'énergie atomique et aux énergies alternatives), which is the French research organisation in the areas of energy, security, information technologies and health technologies, the Université libre de Bruxelles (ULB), Belgium, the University of Coimbra, Portugal, Tunghai University, Taiwan. See the list of the group's external members and of the group's publications for further information.

Currently, the main research topics of the group are the ones listed below.

Future Internet

The group's research supports a Future Internet vision, on the ground of the participation in the large FI-WARE EU-funded project concerning the Future Internet technology foundation and in projects on 5G communications, to develop a technology-independent distributed framework including coordinated control algorithms. These algorithms, based on homogeneous metadata describing the network and user status, manage the network resources and services to maximize the resource exploitation while

satisfying the user requirements. The adopted methodologies include model-free learning, multi-agent systems, cross-layer/cross-network optimization, context awareness, data fusion.

e-Health

The focus of the research activities of the group is related to the design and development of Intelligent Systems to support medical workers in the diagnosis and treatment processes. The group has studied several solutions for medical imaging analytics to provide medical operators with detailed reports of the anomalies and key features detected inside a decision support system. The group has developed customised algorithms for Federated Learning, to allow a GDPR-compliant knowledge sharing solution among networked clinical institutions by enabling the training of distributed Artificial Intelligence systems. Recent research activities focus also on the design of predictive and individualised control algorithms for the insulin treatment of patients using an artificial pancreas.

Smart Energy

The research group tackles several control problems in the smart grid and power systems domain, including: control of renewable energy sources, active demand and demand side management in the residential and commercial sectors, algorithms for smart charging control of plug-in electric vehicles, integration of storage and other distributed energy resources into the grid. The research group has cooperated with several italian and european research centers, universities and industries in many national and european research projects, where it has developed smart grid control algorithms mostly based on model predictive control and nonlinear control techniques (e.g., feedback linearization).

Space

Within this topic, the research group aims at developing control methodologies in the context of space-related applications, such as satellite communication networks along with their interaction with terrestrial (wired and wireless) ones, satellite networks used for emergency prevention, satellite launchers, sensor networks for planetary explorations. The control methodologies are applied in several international research projects funded by ESA and EU and range from classical feedback control of time-delay systems for congestion control problems to distribued non-cooperative control for load balancing and routing problems and deep reinforcement solutions for admission control problems.

The group members are involved in the activities of the Consortium for the Research in Automation and Telecommunications (CRAT), whose members are University of Rome Sapienza, Politecnico di Bari, University of Sannio, Thales Alenia Space Italia and TopNetwork. The aim of CRAT is to carry out applied research in the context of National and European projects and to favour the birth of start-ups. The Sapienza start-up Ares2t was funded by members of the Networked System group on the ground of research in the field of smart grids and smart charging of electric vehicles.

<u>On-going research projects</u>

- FedMedAI, Elaborazione di dati clinici con metodologie di intelligenza artificiale per strutture sanitarie federate nel rispetto del GDPR, April 2021-April 2023, Prot. n. A0375-2020-36491 del 23/10/2020, https://sites.google.com/diag.uniroma1.it/fedmedai/home
- VADUS, Virtual Access and Digitalization for Unreachable Sites, October 2020-October 2022, European Space Agency (ESA), 5G for L'ART programme.
- ARIES, Advanced multi-Rat Integrated multi-sensors solution for Emergency prevention, detection and response operationS (managed by CRAT), November 2020-April 2022, European Space Agency (ESA), 5G for L'ART programme.
- 5G-SOLUTIONS, 5G Solutions for European Citizens (managed by CRAT), June 2019-May 2022, EU H2020-ICT-2019.
- SESAME, Smart European Space Access thru Modern Exploitation of Data Science (managed by CRAT), January 2015 - December 2022, EU H2020-SPACE-16-TEC-2018.
- HyDEMO, HydRON Demonstrator System Phase A/B1", January 2022 - (expected) December 2023 (managed by CRAT), European Space Agency (ESA), HydRON Demonstration System (DS).

Publications

Journal papers

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Proietti Mattia Gabriele, Pietrabissa Antonio, Beraldi Roberto "A Load Balancing Algorithm for Equalising Latency across Fog or Edge Computing Nodes". In: *Ieee Transactions On Services Computing*, (2023), pp. 1 - 12. DOI: 10.1109/TSC.2023.3265883

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Menegatti D., Giuseppi A., Delli Priscoli F., Pietrabissa A., Di Giorgio A., Baldisseri F., Mattioni M., Monaco S., Lanari L., Panfili M., Suraci V. "CADUCEO: A Platform to Support Federated Healthcare Facilities through Artificial Intelligence". In: *Healthcare*, (volume: 11) (2023). DOI: 10.3390/healthcare11152199

Baldisseri Federico, Wrona Andrea, Menegatti Danilo, Pietrabissa Antonio, Battilotti Stefano, Califano Claudia, Cristofaro Andrea, Di Giamberardino Paolo, Facchinei Francisco, Palagi Laura, Giuseppi Alessandro, Delli Priscoli Francesco "Deep Neural Network Regression to Assist Non-Invasive Diagnosis of Portal Hypertension". In: *Healthcare*, (volume: 11) (2023). DOI: 10.3390/healthcare11182603

Di Giorgio Alessandro, De Santis Emanuele, Frettoni Lucia, Felli Stefano, Liberati Francesco "Electric Vehicle Fast Charging: A Congestion-Dependent Stochastic Model Predictive Control Under Uncertain Reference". In: *Energies*, (volume: 16) (2023). DOI: 10.3390/en16031348

Sciancalepore Francesco, Fabozzi Francesco, Albino Giulia, Del Baldo Giada, Di Ruscio Valentina, Laus Beatrice, Menegatti Danilo, Premuselli Roberto, Elena Secco Domitilla, Eugenio Tozzi Alberto, Lacorte Eleonora, Vanacore Nicola, Carai Andrea, Mastronuzzi Angela "Frequency and characterization of cognitive impairments in patients diagnosed with paediatric central nervous system tumours: a systematic review". In: *Frontiers In Oncology*, (2023).

Conference proceedings

Liberati Francesco, De Santis Emanuele, Di Giorgio Alessandro "Adaptive Model Predictive Control for Large-scale Coordinated PEV Recharging". In: *2023 Ieee International Conference On Environment And Electrical Engineering And 2023 Ieee Industrial And Commercial Power Systems Europe (eeeic / I&cps Europe)*, (2023), pp. 1 - 6. DOI: 10.1109/EEEIC/ICPSEurope57605.2023.10194712

Baldisseri F., Montecchiani E., Maiani A., Menegatti D., Giuseppi A., Pietrabissa A., Fogliati V., Priscoli F. D. "Behavioural Cloning for Serious Games in Support of Pediatric Neurorehabilitation". In: *2023 31st Mediterranean Conference On Control And Automation (med) - Proceedings*, (2023), pp. 487 - 492. DOI: 10.1109/MED59994.2023.10185734

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Menegatti Danilo, Giuseppi Alessandro, Pietrabissa Antonio "Distributed MARL with Limited Sensing for Robot Navigation Problems". In: *Ifac-papersonline*, (volume: 56) (2023), pp. - 2037. DOI: 10.1016/j.ifacol.2023.10.1100

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Giuseppi A., Menegatti D., Pietrabissa A. "Stability of Non-Cooperative Load Balancing with Time-Varying Latency". In: *Proceedings Of The Ieee Conference On Decision And Control*, (2023), pp. 7445 - 7450. DOI: 10.1109/CDC49753.2023.10383685

Imran Muhammad, Antonucci Giovanni, Di Giorgio Alessandro, Priscoli Francesco Delli, Tortorelli Andrea, Liberati Francesco "Task Scheduling in Assembly Lines with Single-Agent Deep Reinforcement Learning". In: *Proceedings Of The 2023 9th International Conference On Control, Decision And Information Technologies (codit)*, (2023), pp. - 1588. DOI: 10.1109/CoDIT58514.2023.10284428

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3.5.2 Nonlinear Systems and Control

Research lines:

- Delay Systems
- Discrete-time and Sampled Data Systems
- Distributed estimation
- Epidemic modeling and control
- Feedback linearization
- Hybrid Systems
- Multi-Agent and Multi Robot Systems
- Nonlinear observers
- Optimal Control and Stochastic Systems
- Optimal control for resource management
- Optimal Filtering
- Stochastic stabilisation
- Systems analysis and control

Members: BATTILOTTI Stefano (leader), BENVENUTI Luca, CALIFANO Claudia, DI GIAMBERARDINO Paolo, IACOVIELLO Daniela, MATTIONI Mattia and MONACO Salvatore

Post Docs: D'ANGELO Massimiliano

Research on nonlinear systems and control at the University of Rome La Sapienza has been active since the early 70s and, historically, has played a major role worldwide.

The geometric approach to nonlinear feedback design marked the beginning of a new area of research which, in the subsequent decades, has profoundly influenced the development of the entire field. The concepts of feedback equivalence and zero dynamics, their properties and implications are perhaps the most frequently used concepts in nonlinear feedback design. The natural evolution of the geometric approach from the study of systems evolving on Lie groups, with numerous applications to the control of spacecrafts and mobile robots, to robust regulation under state and output measurements feedback of systems possessing unstable zero dynamics, the use of filtered Lyapunov functions for robust stabilization, the control of networked systems in presence of limited information, till the control of nonlinear delayed systems, state estimators and optimal control for noisy systems with non-Gaussian noise and packet loss, stochastic delay identification. Analysis and design of real control systems integrating devices and computational procedures in a digital context involves ad-hoc methods. Nonlinear discrete-time and sampled data systems are the subjects of an investigation developed at La Sapienza from the early 80s, in a still active cooperation with the Laboratoire des Signaux et Systèmes of the French CNRS. The research activity has been focused on solving nonlinear control problems in discrete-time and on finding digital solutions to continuous-time control systems. One of the major outcomes of the investigation has been the settlement of an original approach, mixed by algebraic and geometric concepts, used either to prove the existence of solutions in discrete-time or to compute approximated solutions in the digital context. From the results on feedback linearization, stabilization, regulation, observer theory, new research lines are in the direction of hybrid, networked and Hamiltonian dynamics. Particular attention is devoted

to the settlement of executable algorithms for computing the proposed solutions. Measurements devices, algorithms, data handling and transmission represent critical aspects in any distributed control problem. The number of devices, their location, the energy consumption, the data-communication links, the distributed data handling, multi-consensus, load balancing, and quality evaluation are nowadays classical concepts in this context. New issues deal with dynamic sensor networks, where mobile platforms are assimilated to intelligent devices, in which motion planning and control problems pose additional requirements and make harder the solution of the task. The full problem formulation as a high dimensional nonlinear dynamic is a challenging interdisciplinary area of research towards easier and cheaper solutions to problems like surveillance, monitoring, decentralized and distributed control. Problems under investigation in this field concern sensor and actuator devices, computation algorithms, local and global coordinated control, network communication protocols, data acquisition and fusion.

Epidemic modeling, analysis and control is a further research line developed by the group. The methodologies of mathematical modeling and system analysis are applied to the study of specific epidemic diseases, like the HIV/AIDS, the measles and, recently, the COVID-19. The research goes through the introduction of ad hoc models, identified by using real data, the characterization the Reproduction Number, together with its relation with the most significant epidemic parameters (contact rates, death rates, time constants of infections, etc), the definition of suitable optimal intervention policies along the possible control channels corresponding to vaccination, prevention with informative campaign, medication, quarantine and isolation (as in the recent COVID 19 emergency). The same kind of modeling analysis and control is successfully applied to computer viruses and cybersecurity. Extension of theoretical aspects (singular control) as well as of applications (dynamics on unemployment) of optimal control are also considered.

The applicative aspects of these research activities are carried out at the Systems and Control Laboratory, founded in 1995. Members of the Nonlinear Systems and Control group have been actively serving in the control community in technical committees and as associate editors for the major journals in the area and conference editorial boards as for both IEEE CSS, IFAC and EUCA.
The research activities, as testified by the scientific production, are developed in collaboration with several national and international institutes as the Laboratoire des Signaux et Systèmes (CNRS, Gif sur Yvette), IRCCyN (CNRS, Nantes), Fondazione Santa Lucia , Cosync Lab (Sapienza University of Rome) and the company BrainTrends, Istituto di Analisi dei Sistemi e Informatica (IASI- CNR) for the modeling, analysis and control of epidemiological models, Universidade do Porto, Centro di Sistemi di Elaborazione e Bio-Informatica (Campus Biomedico), McKelvey School of Engineering (Washington University of St. Louis). Those collaborations also encourage international research training and orientation, with PhD double degrees delivering, in the context of an ad hoc binational program ELISA, which involves Italian and French Institutions.

Publications

Journal papers

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Battilotti Stefano, Cacace Filippo, Califano Claudia, D'angelo Massimiliano "Leader-following consensus with non-uniform and large communication delays". In: *Ieee Transactions On Control Of Network Systems*, (2023).

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3.5.3 Robotics

Research lines:

- Haptic and Locomotion Interfaces
- Humanoid Locomotion
- Medical Robotics
- Mobile Robots
- Motion and Trajectory Planning
- Physical Human-Robot Interaction
- Planning and Control of UAVs
- Robot Learning for Planning and Control
- Robot Modeling and Identification
- Sensor-based Reaction and Planning
- Soft Robotics
- Vision-based Control
- Whole-Body Control of Humanoids

Members: CRISTOFARO Andrea, DE LUCA Alessandro, DE SANTIS Emanuele, FRANCHI Antonio, LANARI Leonardo, ORIOLO Giuseppe, SCIANCA Nicola and VENDITTELLI Marilena

PhD students: BELVEDERE Tommaso, CAPOTONDI Marco, CAPPELLINI Guglielmo, CIPRIANO Michele, D'ORAZIO Francesco, GOVONI Lorenzo, PUSTINA Pietro, SMALDONE Filippo Maria, TARANTOS Spyridon and VICECONTE Paolo Maria

The Robotics group at DIAG, and the associated DIAG Robotics Lab, were established in the late 1980s with a commitment to develop innovative planning and control methods for industrial and service robots. The main research topics are: nonlinear control of robots; control of manipulators with flexible elements (elastic joints, flexible links, variable stiffness actuation); hybrid force/velocity and impedance control of manipulators interacting with the environment; optimization schemes in kinematically redundant robots; motion planning for high-dimensional systems; motion planning and control of wheeled mobile robots and other nonholonomic mechanical systems; control-based motion planning for mobile manipulators; motion planning and control of locomotion in humanoid robots; stabilization of underactuated robots; control of locomotion platforms for VR immersion; sensor-based navigation and exploration in unknown environments; image-based visual serving; control and visual serving for unmanned aerial vehicles (UAV); multi-robot coordination and mutual localization; unsupervised continuous calibration of mobile robots; actuator/sensor fault detection and isolation in robots; safe control of physical human-robot collaboration; sensory supervision of human-robot interaction. Most of our research activities undergo experimental validation in the DIAG Robotics Lab. The current equipment consist of three articulated manipulators (a 6R Universal Robots UR10, a 7R lightweight KUKA LBR4+ with FastResearchInterface, and a 6R KUKA KR5 industrial robot), two haptic interfaces with 3D force feedback (Geomagic Touch), an underactuated system (Pendubot by Quanser), and several mobile robots, including wheeled (a MagellanPro by iRobot, a team of five Khepera III by K-Team), legged (3 NAO humanoid robots by Aldebaran), and flying (a Hummingbird and a Pelican quadrotor

UAVs by AscTec) platforms. These robots are equipped with sensing devices of various complexity, going from ultrasonic/laser range finders to cameras, and stereo vision systems. We have multiple RGB-D sensors, two 6D F/T sensors (Mini45 by ATI), and two HMDs (Oculus Rift). We also have a sensorized platform (Cyberith Virtualizer) for locomotion and VR immersion. In the past, we have designed and built a two-link flexible manipulator (FlexArm) and a differentially-driven wheeled mobile robot (SuperMARIO).

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