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

DIAG Report 2020

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Contents

1 Introduction

The present document is a report about the research activity carried out in 2020 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, system, and management sciences. 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 either in universities or in industries in information technologies, automation, and management. The faculty of DIAG in 2020 consists of 32 full professors, 38 associate professors, and 17 assistant professors (ricercatori). They offer educational services at undergraduate and graduate level to several programs of the two schools of Engineering at Sapienza (Facoltà di Ingegneria dell'Informazione, Informatica e Statistica and Facoltà di Ingegneria civile ed industriale), and at graduate level to the Master in Product Design, of the school of Architecture (Facoltà di Architettura), with main responsibility in the curricula in informatics, systems and control, and engineering management. Details about teaching activities are not reported in this document; a description may be found at http://www.diag.uniroma1.it, under section "Teaching". DIAG offers also two PhD programs, and cooperates with a PhD program offered by another department. They are briefly described in Section 2.4 of this report.
DIAG's research activity is organized in 6 research areas, each composed of one or more research groups. An overview of the groups is reported in Section 3, together with the list of people involved, in 2020.

2 General Information

2.1 Location

The location of DIAG is 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. The Library facilities are also available to students and faculty of other departments and universities. In addition to the normal librarian activity, the Library organized presentations of the department's degree courses (OpenDIAG), conferences on specific topics, and book presentations. The Library has also organized a project for the Alternanza Scuola Lavoro for 20 secondary school students. Finally, the Library staff helps professors to insert the research products in the IRIS database.

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
The laboratory is devoted to the development of autonomous systems for operating in unstructured and rescue environments, as well as vision based systems for navigation, environment reconstruction and recognition.
Web: http://www.diag.uniroma1.it/alcor
Head: Fiora Pirri

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.
Web: https://www.dis.uniroma1.it/node/18225
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.
Web: https://www.dis.uniroma1.it/node/18228
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.
Web: http://infocli31.dislt.uniroma1.it/elsa
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: Alberto Marchetti Spaccamela

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://www.diag.uniroma1.it/labrococo/
Head: Daniele Nardi

Systems and Control Laboratory
Via Ariosto 25 - basement
The laboratory is devoted to the development and experimental verification of new control strategies.
Web: http://www.diag.uniroma1.it/~syscon/
Head: Paolo Di Giamberardino

Web Algorithmics and Data Mining Laboratory (WADAM)
Via Ariosto 25 - room A220, wing A2
The laboratory is devoted to the design of algorithms for web and data-mining related problems.
Web: http://wadam.diag.uniroma1.it
Head: Aris Anagnostopoulos

Wireless Sensor Networks Laboratory
Via Ariosto 25 - basement
The laboratory is devoted to the development and experimental verification of protocols and algorithms for WSNs.
Web: https://www.dis.uniroma1.it/node/18236
Head: Andrea Vitaletti

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.

Computer Science Laboratory Paolo Ercoli for introductory courses
Via Tiburtina 205, Roma
About 150 stations are available for undergraduate teaching.
Web: http://tibur.diag.uniroma1.it
Head: Camil Demetrescu

PC and Workstations Laboratory Paolo Ercoli for advanced courses
Via Eudossiana 18, Roma
About 75 PC and workstations are available for the graduate teaching.
Web: http://www.ing.uniroma1.it
Head: Umberto Nanni

2.3 People

Head of department: Tiziana CATARCI
Administration head: Fabio TUFILLI

Professors

Roberto BALDONI
Stefano BATTILOTTI
Giuseppe CATALANO
Tiziana CATARCI
Bruno CICIANI
Febo CINCOTTI
Cinzia DARAIO
Giuseppe DE GIACOMO
Alessandro DE LUCA
Francesco DELLI PRISCOLI
Camil DEMETRESCU
Gianni DI PILLO
Francisco FACCHINEI
Luca IOCCHI
Alberto ISIDORI
Maurizio LENZERINI
Stefano LEONARDI
Stefano LUCIDI
Alberto MARCHETTI SPACCAMELA
Salvatore MONACO
Umberto NANNI
Daniele NARDI
Alberto NASTASI
Giuseppe ORIOLO
Laura PALAGI
Fiora PIRRI
Pierfrancesco REVERBERI
Riccardo ROSATI
Francesca SANNA RANDACCIO
Antonio SASSANO
Marco SCHAERF

Associate professors

Aris ANAGNOSTOPOULOS
Laura ASTOLFI
Alessandro AVENALI
Luca BECCHETTI
Luca BENVENUTI
Roberto BERALDI
Silvia BONOMI
Renato BRUNI
Claudia CALIFANO
Ioannis CHATZIGIANNAKIS
Idiano D'ADAMO
Tiziana D'ALFONSO
Fabrizio D'AMORE
Rosa Maria DANGELICO
Alberto DE SANTIS
Marianna DE SANTIS
Alessandro DI GIORGIO
Francesca DI PILLO
Lorenzo FARINA
Giorgio GRISETTI
Daniela IACOVIELLO
Leonardo LANARI
Domenico LEMBO
Paolo LIBERATORE
Giorgio MATTEUCCI
Massimo MECELLA
Christian NAPOLI
Fabio NONINO
Paola PACI
Fabio PATRIZI
Antonio PIETRABISSA
Leonardo QUERZONI
Massimo ROMA
Giuseppe SANTUCCI
Roberta SESTINI
Fabrizio SILVESTRI
Marco TEMPERINI
Marilena VENDITTELLI
Andrea VITALETTI

Assistant professors (ricercatori)

Irene AMERINI
Roberto CAPOBIANCO
Thomas Alessandro CIARFUGLIA
Marco CONSOLE
Chiara CONTI
Emilio COPPA

Andrea CRISTOFARO
Paolo DI GIAMBERARDINO
Giuseppe Antonio DI LUNA
Adriano FAZZONE
Luca FRACCASCIA
Riccardo LAZZERETTI
Francesco LEOTTA
Giampaolo LIUZZI
Andrea MARRELLA
Riccardo MARZANO
Mattia MATTIONI
Valsamis NTOUSKOS
Manuela PETTI
Paolo RUSSO
Simone SAGRATELLA
Chris SCHWIEGELSHOHN
Jlenia TOPPI

Post doc (research associates) and research assistant

Khaled AL KHUDIR
Georgios AMANATIDIS
Marco ANGELINI
Alessandro ANNARELLI
Georgios BIRMPAS
Camillo CARLINI
Massimo CEFALO
Angela CIARAMIDARO
Gianluca CIMA
Emma COLAMARINO
Massimiliano D'ANGELO
Daniele Cono D'ELIA
Pierangelo DI SANZO
Antonio DI STASIO
Giovanni FARINA
Marco FERRO
Claudio Roberto GAZ
Alessandro GIUSEPPI
Maram KHATIB
Philip LAZOS
Lorenzo LEPORE
Francesco LIBERATI
Federico LISI
Emanuele MAGRINI
Jerin George MATHEW
Valerio MODUGNO
Giulia PALOMBI
Martina PANFILI
Alessandro PELLEGRINI
Ramon Fraga PEREIRA
Giuseppe PERELLI
Maria Grazia PUXEDDU
Giammarco QUAGLIA
Rebecca REIFFENHAUSER
Francesco RICCIO
Capobianco ROBERTO
Alessandro RONCA
Giacomo RONCONI
Marco RUZZI
Valerio SANTARELLI
Marta SANZARI
Nicola SCIANCA
Luigi VONA
Temirlan ZHARKYNBEK
Shufang ZHU

Administration staff

Antonella CANCELLIERI
Federica CANNELLI
Ugo CINELLI
Sara CIOTTI
Annalisa CIRINNA'
Andrea DORI
Sabrina GIAMPAOLETTI
Luciano GRANDI
Domenico MACARI
Giulia OLIVIERI
Marcello PANI
Roberta PROIETTI SEMPRONI
Tiziana TONI
Fabio TUFILLI
Concetta VELLA

2.4 Doctoral programs

DIAG hosts the PhD programs in Automatic Control, Bioengineering and Operations Research, in Data Science and in Engineering in Computer Science.
Website: http://www.diag.uniroma1.it/dottorati-di-ricerca

Automatic Control, Bioengineering and Operations Research

Coordinator: Giuseppe Oriolo

The Academic Board of the PhD program in Automatic Control, Bioengineering and Operations Research is coordinated by Giuseppe ORIOLO. This PhD program is the result of merging the two former PhD programs in Systems Engineering and in Operations Research, and has now three curricula, i.e., Automatic Control, Bioengineering, and Operations Research. The research topics are: systems theory, nonlinear and optimal control, control applications, robotics, networked systems, metabolic systems, neuroengineering, bioinformatics, bioelectrical signal processing, combinatorial optimization, nonlinear programming, network design, neural networks, logistics.

PhD students

XXXII course

Maria Laura ACETO
Yuri ANTONACCI
Tommaso COLOMBO
Massimiliano D'ANGELO
Eduardo FRANCO
Giorgio GRANI
Maram KHATIB
Hayman Salih MOHAMMED
Maria Grazia PUXEDDU

XXXIII course

Francesco CURIA
Danny D'AGOSTINO
Alessio MORESCHINI
Antonio ORNATELLI
Francesco ROMITO
Mirko ROSSI
Ruggiero SECCIA
Andrea TORTORELLI

XXXIV course

Marco BORESTA
Anna Livia CROELLA
Mohamed ELOBAID
Roberto GERMANÀ
Andrea ILGRANDE
Esteban SALGADO
Spyridon TARANTOS
Edoardo Maria TRONCI

XXXV course

Valerio AGASUCCI
Emanuele DE SANTIS
Valeria DE SETA
Andrea DI STEFANO
Manuel DONSANTE
Muhammad IMRAN
Aldo LAZICH
Diego Maria PINTO
Edoardo Maria POLO

XXXVI course

Tommaso BELVEDERE
Alice CALAMITA
Michele CIPRIANO
Federico D'ONOFRIO
Danilo MENEGATTI
Davide MEROLLA
Marta MONACI
Andrea TANTUCCI
Andrea WRONA

PhD theses completed in 2020

Alessandro GIUSEPPI
Control methods for safe and efficient cyber-physical systems
Supervisor: Francesco Delli Priscoli

Eduardo FERREIRA FRANCO
A dynamical evaluation framework for technical debt management in software maintenance process
Supervisor: Paolo Dell'Olmo

Giorgio GRANI
Criterion space search algorithms for nonlinear integer multiobjective programs
Supervisor: Laura Palagi

Maram KHATIB
Multi-sensor coordination in human-robot interaction
Supervisor: Alessandro De Luca

Maria Grazia PUXEDDU
The structural and functional multilayer modular organization of the human brain
Supervisor: Laura Astolfi

Massimiliano D'ANGELO
LQ regulators and detection problems in non-gaussian environments
Supervisor: Stefano Battilotti

Nicola SCIANCA
Humanoid gait generation via MPC: Stability, robustness and extensions
Supervisor: Giuseppe Oriolo

Tommaso COLOMBO
Optimization techniques for large scale finite sum problems
Supervisor: Stefano Lucidi

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 economic and social 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: i)

Advanced digital platforms, ii) Management of urban spaces and environmental resources, iii) Medicine and health, iv) Economic and Social Analysis.

PhD students

XXXIV course

Giorgio BARNABO
Federico FUSCO
Lorenzo LASTILLA
Leonardo MARTINI
Giovanni TRAPPOLINI

XXXV course

Matteo BOHM
Valerio GUARRASI
Tommaso LANCIANO
Luca MAIANO
Andrea MARCOCCHIA
Valerio MARSOCCI
Andrea MASTROPIETRO
Timur OBUKHOV
Giuseppe PASCULLI
Marco ZECCHINI

XXXVI course

Carlo ABRATE
Maria Sofia BUCARELLI
Federico CINUS
Gabriele D'ACUNTO
Riccardo DENNI
Giulia DI TEODORO
Lorenzo GIUSTI
Maryam KAMAL
Francesco MOGAVERO
Federico SICILIANO

Engineering in Computer Science

Coordinator: Camil Demetrescu

The Academic Board of the PhD program in Engineering in Computer Science is coordinated by Camil DEMETRESCU. The research topics include: theory of algorithms, computer systems, databases, programming languages, theoretical computer science, image processing, artificial intelligence, cognitive robotics, VLSI, computational logics, performance evaluation, distributed software architectures, human-computer interaction, computer networks and security.

PhD students

XXXII course

Hanteer OBAIDA
Francesco PUJA
Paolo RUSSO
Filipp SAMOILOV
Lun WANG

XXXIII course

Irvin ALOISE
Mirco COLOSI
Stefano CONOCI
Federico CROCE
Antonio D'INNOCENTE
Michele GENTILI
Simone LENTI
Luca MASSARELLI
Cristina MENGHINI
Francesco SAPIO
Federico SCAFOGLIERI
Emiliano SILVESTRI

XXXIV course

Simone AGOSTINELLI
Edoardo ALATI
Graziano BLASILLI
Luca BORZACCHIELLO
Lorenzo BRIGATO
Carlos Salvador CARBONE LORIO
Stefano CARNA
Jim Martin CATACORA OCANA
Jesus Fernando CEVALLOS MORENO

Paolo FANTOZZI
Marco FAVORITO
Mulham FAWAKHERJI
Lauren Stacey FERRO
Manuel NAMICI

XXXV course

Emanuele ANTONIONI
Eleonora BERNASCONI
Pietro BORRELLO
Francesco CHIARIELLO
Bacocco DUILIO LUCA
Mahboobeh ESTAKHRI ESTAHBANATI
Luigi FEOLA
Serena FERRACCI
Francesco FUGGITTI
Tiziano GUADAGNINO
Lorenzo MAURO
Alessia PALLESCHI
Andrea PICCIONE
Gabriele PROIETTI MATTIA
Elena UMILI

XXXV course

Fiorella ARTUSO
Enkeleda BARDHI
Barbara BAZZANA
Dario BENVENUTI
Nicolò BRANDIZZI
Damiano BRUNORI
Patrizia CARELLO
Roberto CIPOLLONE
Francesca CONSOLE
Marco CUOCI
Luca DI GIAMMARINO
Emiliano DI RETO
Mikhail GRAZHDANKIN
Sara KASZUBA
Biagio LA ROSA
Lorenzo MARCONI
Gabriel PALUDO LICKS
Adriano PIMPINI
Vincenzo SURIANI
Silvestro V. VENERUSO

PhD theses completed in 2020

Albani Dario
Monitoring, Mapping and Exploitation by Self Organizing Robot Swarms
Supervisor: Daniele Nardi

Aloise Irvin
Exploiting Non-Minimal Parametrizations in Graph-Based SLAM
Supervisor: Giorgio Grisetti

Cima Gianluca
Abstraction in Ontology-based Data Management
Supervisor: Maurizio Lenzerini

Colosi Mirco
Standardizing SLAM: exploiting recurrent patterns for modularity and behavioral robustness
Supervisor: Giorgio Grisetti

Farina Giovanni
Tractable Reliable Communication in Compromised Networks
Supervisor: Silvia Bonomi

Mancini Massimiliano
Towards Recognizing New Semantic Concepts in New Visual Domains
Supervisor: Barbara Caputo

Massouh Nizar
Learning To Learn Objects From The WEB
Supervisor: Luca Iocchi

Schlegel Dominik
Stereo Visual SLAM and Place Recognition with Binary Feature Descriptors
Supervisor: Giorgio Grisetti

2.5 Visiting Scientists and Scholars

- Cristiano GIUFFRIDA, Vrije Universiteit Amsterdam, February 2020 to March 2020.
- Yves LESPéRANCE, York University, Toronto, ON, Canada, August 2020 to January 2021.
- Claude MOOG, Laboratoire des Sciences du Numerique de Nantes, France, January 2019 to February 20120.

2.6 Seminars and Workshops

Many scientists are invited to deliver seminars at DIAG. Below we report the list of seminars for the year 2020, in chronological order. We also report the workshops and special scientific events organized at DIAG.

- January 9, 2020, Joanna Wolszczak-Derlacz: *Quality of Non Academic staff and its impact on the Performance: an Exploration on European Universities*.
- January 17, 2020, Claude Moog: *Structural accessibility and structural observability of networked systems, with examples from biology*.
- January 22, 2020, Claudio Pacchierotti: *Wearable haptic technologies for robotics and immersive virtual environments*.
- January 23, 2020, Paola Paci: *Public Seminar*.
- January 23, 2020, Idiano D'Adamo: *Public Seminar*.
- January 24, 2020, Leonardo Querzoni: *Build, Run, Survive: how to design efficient systems that can withstand adversarial settings*.
- January 30, 2020, Georgios Birmpas: *Cost Sharing over Combinatorial Domains*.
- January 30, 2020, Paulo Augusto Cauchick-Miguel: *Publication in high impact journals: an author point of view*.
- February 10, 2020, Nadali, D, Sbrilli, A., Merialdo,P., Ferrara, S.: *Data Science for Humanities - Data Science PhD Course*.
- February 13, 2020, Laura Palagi: *Nonlinear optimization algorithms and models: MINLP, Machine Learning and applications*.
- February 13, 2020, Marco Baity Jesi: *Landscape and Training Dynamics of DNNs: lessons from physics-inspired methods*.
- February 13, 2020, Daniela Iacoviello: *Some results on optimal control applied to epidemics*.
- February 13, 2020, Renato Bruni: *Public Seminar*.
- February 17, 2020, Fabio Sciarrino: *Quantum supremacy: status and perspectives*.
- February 20, 2020, *Automazione: La figura professionale dell'Ingegnere - 2° Incontro tra aziende e studenti*.
- February 24, 2020: *Games, Dynamics and Optimization (GDO2020)*.
- March 2, 2020, Leopold Simar: *Nonparametric Estimation of Efficiency in the Presence of Environmental Variables*.
- March 3, 2020, Cristiano Giuffrida: *Software Exploitation: Hardware is the New Black*.

- March 9, 2020, Alessio Farcomeni, Chris Schwiegelshohn: *Computational and Statistical Methods of Data Reduction - Data Science PhD Course*.
- March 9, 2020, Zahra Ziran: *Text alignment in early printed books combining deep learning and dynamic programming*.
- March 18, 2020, Paolo Di Giamberardino: *Modeling and optimal control of computer virus propagation.*
- March 20, 2020, Mattia Mattioni: *Almost equitable partitions and geometry of the network structure: Applications to cyber-physical systems*.
- April 15, 2020, Paolo Di Giamberardino, Daniela Iacoviello: *2020 ABRO Course on Advances in Automatic Control*.
- April 16, 2020, Febo Cincotti: *Brain-Computer Interfaces for Neurorehabilitation: Design and Application.*
- April 17, 2020, Salvatore Monaco: *2020 ABRO Course on Advances in Automatic Control.*
- April 22, 2020, Andrea Cristofaro: *2020 ABRO Course on Advances in Automatic Control.*
- April 22, 2020, Ioannis Chatzigiannaki, Francesco Leotta: *PhD Course on Smart Environments: Technologies, state of the art and research challenges*
- April 24, 2020, Francesco Liberati: *2020 ABRO Course on Advances in Automatic Control.*
- April 27, 2020, Chiara Conti: *Technological innovation, externalities, and public policies.*
- May 11, 2020, Serena Arima, Chris Schwiegelshohn: *Data Science PhD course on Computational and Statistical Methods of Data Reduction*.
- May 19, 2020, Felice Lopresto: *Presentazione del libro di Felice Lopresto*.
- May 20, 2020, Maria Antonia Brovelli, Augusto Mazzoni: *Data Science for Geographical Information System Applications - Data Science PhD Course.*
- May 22, 2020, Fabrizio Silvestri: *Robustness in Language Models: From Misspelling Resistant Embedding to Fact Checkable Text Generation.*
- May 22, 2020, Francesca Di Pillo: *Economic and regulatory issues of public utilities: a focus on energy and waste.*
- May 23, 2020, Giampaolo Liuzzi: *Derivative-free methods for black-box optimization problems.*
- May 25, 2020, Riccardo Marzano: *Antitrust and firm behavior.*
- May 28, 2020, Andrea Guerrini: *Regolazione economica e impatti sulla performance delle utility*.
- June 8, 2020, *Data Science PhD Course - Data Science and Network Medicine for Health and Medical Research*.
- July 6, 2020, Mattia Mattioni: *On the control of nonlinear systems under sampling and delays*.
- July 7, 2020, Cinzia Daraio: *What do we know about Efficiency, Effectiveness and Impact of Education and Research?*
- September 16, 2020, Marco Console: *Incomplete information in data management*.
- September 16, 2020, Emilio Coppa: *Finding bugs and vulnerabilities in real-world software.*
- October 14, 2020, Maurizio Lenzerini: *Query Answering and Query Abstraction through Ontologies*.
- October 21, 2020, Simone Sagratella: *A sequential optimization approach for multi-follower games.*
- November 19, 2020, Massimo Mecella: *A journey through service architectures and process management towards resilient and dynamic smart enterprises.*
- December 3, 2020, Tiziana Catarci: *Per una nuova etica dell'intelligenza artificiale: le tecnologie rinnovano e cambiano l'umano*.
- December 15, 2020, Thomas Ciarfuglia: *A research report on data driven approaches to robot perception for navigation and other applications*.

2.7 Other institutional activities

February 1, 2020 to October 2, 2020: Emilio Coppa, Camil Demetrescu, Riccardo Lazzeretti and Leonardo Querzoni *CyberChallenge.IT - Nodo locale Sapienza*
February 6, 2020: Marco Angelini, Leonardo Querzoni *ITASEC2020 Framework Special Day*
February 18, 2020: Leonardo Querzoni *Seminario presso il CERTFIN Cyber Knowledge and Security Awareness Observatory*
February 19, 2020: *Ragazze e ICT - Radio3 Scienza*
February 20, 2020: Alessandro De Luca *ANIPLA 2nd Meeting on Automation: Professional opportunities for engineers*
February 27, 2020: *Rivoluzione 4.0*
April 30, 2020: *Fortune - Ricostruzione*
June 15, 2020 to September 15, 2021: *docenza presso Banca d'Italia in due edizioni di un corso su "Data Management for Big Data Analysis"*
July 1, 2020 to July 2, 2020: *Armonicamente 4.0*
July 7, 2020: *Intelligenza Artificiale applicata all'editoria*
July 23, 2020: *AI for future Italy*
November 1, 2020 to March 29, 2021: Silvia Bonomi *Partecipazione al gruppo di lavoro CyberEquality.it*
November 4, 2020: *Corso ANSA giornalismo e IA*
December 3, 2020: *Convegno Società Italiana per l'Etica nell'IA*

2.8 Honours and Awards

- Domenico Lembo, Federico Scafoglieri *ISWC 2021 best poster demo or award*, ISWC 2021 best poster demo or award, for the demonstration "Ontology Mediated Information Extraction with MASTRO SYSTEM-T" by Domenico Lembo, Yunyao Li, Lucian Popa, Kun Qian and Federico Scafoglieri.
- Daniele Cono D'Elia *Relatore Premio Tesi «Innovare la sicurezza delle informazioni» CLUSIT*, Relatore per le attività di tesi dello studente Cristian Assaiante, risultato vincitore del primo premio per il Premio Tesi «Innovare la sicurezza delle informazioni» (16a edizione, 2020) organizzato dal CLUSIT.Estratto dal sito CLUSIT: Il premio "Innovare la sicurezza delle Informazioni", riservato alle tesi universitarie più innovative in materia di sicurezza informatica, ha lo scopo di promuovere una collaborazione tra i soggetti che si occupano di sicurezza informatica in Italia: le aziende, le Università, gli studenti. Un punto di scambio tra mondo produttivo e mondo scientifico, tra studenti e mondo del lavoro, alimentato direttamente dai singoli soggetti che vi partecipano portando i propri bisogni e le proprie esperienze.Titolo della tesi: A Micro-Architectural Red PillCorso: Laurea in Ingegneria Informatica e Automatica
- Daniele Cono D'Elia *Borse di viaggio in Corea del Sud per giovani ricercatori italiani,* L'Ambasciata d'Italia a Seoul ritiene strategico fornire a giovani ricercatori italiani, che non abbiano ancora compiuto i 35 anni, l'opportunità di stabilire collaborazioni durature con i loro colleghi coreani tramite sostegno finanziario e logistico. Il progetto presentato riguarda temi di software security e di systems security portati avanti negli ultimi anni dal proponente. Per maggiori informazioni consultare i link al bando e all'esito della selezione.
- Laura Palagi *Best Paper Award - Journal of Global Optimization*, Journal of Global Optimization Best Paper Award was established by Springer in 2011. It is awarded annually for a paper published in the previous year and consists of $1,000 cash prize. The winners are selected by a committee consisting of several editorial board members.

Among the Award Recipients 2020 (for 2019 publications) Global optimization issues in deep network regression Laura Palagi

- Alessandro Giuseppi *Telespazio Technology Contest 2020*, Dr. Alessandro Giuseppi, researcher of the DIAG research group "Networked Systems", Syed Saad Saif and Alessandro Santopaolo, students of the Master in Control Engineering, won the Telespazio Technology Contest 2020 (T-TeC 2020), which involved 20 Universities from all around Europe, in the "Photon" category, dedicated to scientific innovations in the aerospace field.The team presented a project that combines control systems and Deep Learning methodologies for the prediction and management of wildfires on the basis of satellite data.Date: December 15th, 2020
- Christian Napoli *Pro-quality grant for publications issued TOP1 and TOP10 journals*, Pro-quality grant for publication issued TOP1 and TOP10 journals as part of the Excellence Initiative - Research University Program of the Silesian University of Technology.
- Christian Napoli *Pro-quality grant for publications issued TOP1 and TOP10 journals*, Pro-quality grant for publication issued TOP1 and TOP10 journals as part of the Excellence Initiative - Research University Program of the Silesian University of Technology.
- Leonardo Lanari, Giuseppe Oriolo *2020 IEEE Robotics and Automation Magazine Best Paper Award*, The award, sponsored by the IEEE Robotics and Automation Society, recognizes the best peer-reviewed paper of the IEEE Robotics and Automation Magazine (RAM) published in the previous calendar year. See here.

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.

Companies

- BitBrain - B2B: Brain-to-Brain Connectivity for the Real-time Monitoring of Social Interactions, Laura Astolfi, € 29000, ending 15-03-2023

European Union (EU)

- ERASMUS+ - 9 CONVERSATIONS - Network building for self-employment of refugees, Marco Temperini, € 35099, ending 30-09-2021
- H2020 - AI4EU - A European AI On Demand Platform and Ecosystem, Daniele Nardi, € 78206,00, ending 31-12-2021
- H2020-ERC - AMDROMA - Algorithmic and Mechanism Design Research in Online MArkets, Stefano Leonardi, € 1780150,00, ending 30-06-2023
- H2020 EUROBENCH - BEAST - Benchmark-Enabling Active Shopping Trolley, Luca Iocchi , € 45000,00, ending 31-01-2021
- Sapienza Università di Roma - Bubbles: Defining the BUilding Basic BLocks for a U-Space SEparation Management Service, Luca Iocchi , ending 31-10-2022
- H2020 - DESTINI - Smart Data ProcESsing and SysTems of Deep INsIght, Massimo Mecella, € 166223, ending 30-09-2022
- H2020 MSCA - DOCMA - Disorders of Consciousness (DoC): enhancing the transfer of knowledge and professional skills on evidence-based interventions and validated

technology for a better management of patients, Febo Cincotti, € 126000,00, ending 31-12-2021

- H2020 MSCA - FIRST - virtual Factories: Interoperation suppoRting buSiness innovaTion, Massimo Mecella, € 207000,00, ending 31-12-2021
- ERASMUS+ - IND 4.0 - Master Degree in Industry 4.0, Ioannis Chatzigiannakis , € 55245, ending 14-11-2022
- H2020 EUROBENCH - MADROB - Modular Active Door for RObot Benchmarking, Luca Iocchi , € 45000,00, ending 31-01-2021
- H2020 - PANACEA - Protection and privAcy of hospital and health iNfrastructures with smArt Cyber sEcurity and cyber threat toolkit for dAta and people, Silvia Bonomi, Giuseppe Santucci, € 322500,00, ending 31-12-2021
- ERASMUS+ - PMBOG - Project Management Board Game, Fabio Nonino , € 59560, ending 31-08-2022
- H2020 - RISIS2 - European Research Infrastructure for Science, technology and Innovation policy Studies 2, Cinzia Daraio , € 190625,00, ending 31-12-2022
- H2020 - SCIROC - European Robotics League plus Smart Cities Robot Competitions, Daniele Nardi, € 300000,00, ending 31-01-2022
- H2020 - SECONDHANDS - SecondHands: A Robot Assistant For Industrial Maintenance Tasks, Fiora Pirri, € 993750,00, ending 30-04-2020
- H2020-INFRAIA-2019-1 - SoBigData++ - European Integrated Infrastructure for Social Mining and Big Data Analytics, Stefano Leonardi, € 220000, ending 31-12-2023
- Sapienza Università di Roma - Tailor: Foundations of Trustworthy AI - Integrating Reasoning, Learning and Optimization, Maurizio Lenzerini, € 308175, ending 31-08-2023
- H2020-ERC - WhiteMech - White-Box Self-Programming Mechanisms, Giuseppe De Giacomo, € 2499197,00, 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 Institutions

- MIUR-PRIN 2017 - ALGADIMAR - ALgorithms, GAmes and DIgital MARkets, Stefano Leonardi, € 139990,00, ending 28-02-2023
- Regione Lazio - Direzione regionale infrastrutture e mobilitá - Attivitá di richiesta e supporto per attivitá di intervento per aggiornamento studio preliminare volto alla individuazione del costo efficiente per la gestione delle Ferrovie concesse Regione Lazio, Luca Iocchi , € 35000, ending 31-01-2021
- Regione Lazio - ECORETE GREEN - ECONOMIA CIRCOLARE: Recupero di plastiche e legno con tecnologie green, Rosa Maria Dangelico , € 60042, ending 24-12-2021
- MIUR-PRIN 2017 - GREEN TAGS - Chipless radio frequency identification (RFID) for GREEN TAGging and Sensing, Christian Napoli, € 169000,00, ending 28-02-2023
- MIUR-PRIN 2017 - HOPE - High quality Open data Publishing and Enrichment, Maurizio Lenzerini , € 183737,00, ending 28-02-2023
- Ministero della Salute - RECOMmENceR: RE-establishing COrtico Muscolar COMunication to ENhance Recovery. Clinical validation of BCI-controlled Functional Electrical Stimulation for upper limb rehabilitation after stroke, Jlenia Toppi, € 57222,00, ending 01-12-2022
- Ministero della Salute, Ricerca Finalizzata - RECOMmENceR: RE-establishing COrtico Muscolar COMunication to ENhance Recovery. Clinical validation of BCI-controlled

Functional Electrical Stimulation for upper limb rehabilitation after stroke, Jlenia Toppi, € 57222, ending 01-12-2022

- Ministero della Salute - Ricerca Finalizzata 2018 - IRCCS Fondazione Santa Lucia - The PROMOTOER: a Brain Computer Interface-based intervention that promotes upper limb functional motor recovery in subacute stroke patients. A randomized controlled trial ..., Febo Cincotti, ending 01-12-2022

Research Agreements (Convenzioni)

- Braintrends Srl, ending 28-07-2020
- Centro di Ricerca per gli alimenti e nutrizione CREA, ending 23-01-2020
- IASI CNR, ending 28-07-2020
- Join Study Agreement between DIAG and IBM Almaden Research Lab, Domenico Lembo, ending 01-11-2020
- Universidate do Porto, ending 23-01-2021

Non-EU Institutions

- Promobiia Foundation - DISCLOSE: A new toolbox for the EEG-based assessment of DoC patients, Laura Astolfi, € 15000, ending 31-07-2020
- H2020-MSCA-RISE - DOCMA - Disorders of Consciousness (DoC): enhancing the transfer of knowledge and professional skills on evidence-based interventions and validated technology for a better MAnagement of patients, Jlenia Toppi, € 74700, ending 31-12-2021

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: ASTOLFI Laura, CINCOTTI Febo (leader), FARINA Lorenzo, PACI Paola, PETTI Manuela and TOPPI Jlenia

Post Docs: COLAMARINO Emma and PUXEDDU Maria Grazia

PhD students: ANTONACCI Yuri and DE SETA Valeria

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;
- 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;
- 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: Dip. di Fisiologia Umana e Farmacologia, Sapienza Università di Roma; Dip. di Biotecnologie Cellulari ed Ematologia, Sapienza Università di Roma; Dip. di Medicina sperimentale, laboratorio di Oncogenomica, Sapienza Università di Roma, Laboratorio di Oncogenesi Molecolare, Istituto Nazionale Tumori Regina Elena (Roma); Istituto di Analisi dei Sistemi e Informatica (IASI) – CNR (Roma); Laboratorio di Genetica Agraria, Dipartimento di Biotecnologie, Università 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), Università 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

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Zhang Yu, Wu Wei, Toll Russell T, Naparstek Sharon, Maron-katz Adi, Watts Mallissa, Gordon Joseph, Jeong Jisoo, Astolfi Laura, Shpigel Emmanuel, Longwell Parker, Sarhadi Kamron,

El-said Dawlat, Li Yuanqing, Cooper Crystal, Chin-fatt Cherise, Arns Martijn, Goodkind Madeleine S, Trivedi Madhukar H, Marmar Charles R, Etkin Amit "Identification of psychiatric disorder subtypes from functional connectivity patterns in resting-state electroencephalography". In: *Nature Biomedical Engineering*, (2020). DOI: 10.1038/s41551-020-00614-8

Puxeddu M. G., Faskowitz J., Betzel R. F., Petti M., Astolfi L., Sporns O. "The modular organization of brain cortical connectivity across the human lifespan". In: *Neuroimage*, (volume: 218) (2020). DOI: 10.1016/j.neuroimage.2020.116974

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Belardinilli Francesca, Capalbo Carlo, Malapelle Umberto, Pisapia Pasquale, Raimondo Domenico, Milanetti Edoardo, Mahdavian Yasaman, Liccardi Carlotta, Paci Paola, Sibilio Pasquale, Pepe Francesco, Bonfiglio Caterina, Mezi Silvia, Magri Valentina, Coppa Anna, Nicolussi Arianna, Gradilone Angela, Petroni Marialaura, Di Giulio Stefano, Fabretti Francesca, Infante Paola, Coni Sonia, Canettieri Gianluca, Troncone Giancarlo, Giannini Giuseppe "Clinical Multigene Panel Sequencing Identifies Distinct Mutational Association Patterns in Metastatic Colorectal Cancer". In: *Frontiers In Oncology*, (volume: 10) (2020). DOI: 10.3389/fonc.2020.00560

Vernocchi P., Gili T., Conte F., Del Chierico F., Conta G., Miccheli A., Botticelli A., Paci P., Caldarelli G., Nuti M., Marchetti P., Putignani L. "Network analysis of gut microbiome and metabolome to discover microbiota-linked biomarkers in patients affected by non-small cell lung cancer". In: *International Journal Of Molecular Sciences*, (volume: 21) (2020), pp. 1 - 19. DOI: 10.3390/ijms21228730

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3.2 Engineering in Computer Science

3.2.1 Algorithm Design and Engineering

Research lines:

- Algorithmic approaches for bioinformatics and elearning
- Algorithmic Game Theory
- Approximation and On-line Algorithms
- Experimental Algorithmics
- External Memory and Streaming Algorithms for Massive Data Processing
- Incremental Algorithms and Dynamic Data Structures
- Principles of Design and Analysis of Algorithms

Members: ANAGNOSTOPOULOS Aris, AUSIELLO Giorgio, COPPA Emilio, D'AMORE Fabrizio, DEMETRESCU Camil (leader), LEONARDI Stefano, MARCHETTI SPACCAMELA Alberto and NANNI Umberto

Post Docs: D'ELIA Daniele Cono

Research activity regarding design and engineering of computer algorithms and computational complexity analysis has been developed at DIAG since when the Department has been created in the early Eighties. In the first years the emphasis has been on theoretical aspects such as those related to the notion of approximation preserving reductions among optimization problems and the classification of optimization problems based on their approximability properties. Subsequently, research activities have evolved in various directions according to the evolution of information technology and of application domains. New emerging topics have been addressed such as dynamic graph algorithms, on line algorithms, external memory, and streaming algorithms for massive data sets. Also the emphasis of the approach has changed moving from traditional worst case analysis to experimental performance analysis.
The most relevant recent results include contributions in the following areas:

- Principles of Design and Analysis of Algorithms: re-optimization techniques for combinatorial problems, models of computation for very large data sets;
- Experimental Algorithmics: implementation and engineering of advanced algo- rithms and data structures for graph problems;
- Performance Engineering: design and implementation of methodologies and tools for analying and optimizing software systems;
- External Memory and Streaming Algorithms for Massive Data Processing: external-memory and streaming algorithms for very large graph problems;
- Incremental Algorithms and Dynamic Data Structures: incremental algorithms for path problems in graphs;
- Approximation and On-line Algorithms: scheduling algorithms, algorithms for metabolic networks, vehicle routing, approximation algorithms for rent-or-buy net-work design problems, on-line algorithms for stochastic optimization problems such as Steiner tree and set cover under several models;
- Algorithmic Game Theory: quality of strong equilibria in network formation games under restricted communication model;
- Algorithmic approaches for bioinformatics and elearning: application of algorith- mic models and techniques to bioinformatics and elearning.

In the future we plan to tackle fundamental problems arising in emerging applications involving the analysis and optimization of networks, real-time systems, scheduling and resource allocation, as well as in other areas. Special emphasis will be given to problems on very large data sets and multi-core platforms. In particular, our research goals include:

- External Memory and Streaming Algorithms for Massive Data Processing: external-memory and streaming algorithms for problems arising in the dynamic analysis of large software systems and networks. Among other goals, we plan to investigate novel approaches to performance profiling and optimization based on provably efficient streaming techniques;
- Incremental Algorithms and Dynamic Data Structures: we will study efficient incremental change propagation techniques for constraint-based systems on multi-core platforms;
- Approximation and On-line Algorithms: we aim at investigating the complexity and the approximability of combinatorial resource allocation problems, with a fo- cus on problems arising from the scheduling of recurrent tasks in real-time sys- tems. In particular, we aim at the design and analysis of efficient tests of feasibility for the scheduling of tasks on multiprocessor platforms. We will push further the study of on-line algorithms for stochastic optimization problems. We'll also con- sider the simultaneous approximation on several objective functions and on net- work instances;
- Algorithmic approaches for bioinformatics and elearning: several models and techniques, studied and evolved within the area of algorithm engineering turned out to be very pervasive. In various contexts these has lead to effective solutions to problems with complex structure. In the last years we have devised representa- tions, based on graphs and hypergraphs, suitable to model processes and biologi- cal systems. Then, working with groups of researchers in other disciplines - such as bioinformatics and elearning - we aim at boosting research results in these areas.

3.2.2 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, FAZZONE Adriano, LEONARDI Stefano (leader), SCHWIEGELSHOHN Chris and SILVESTRI Fabrizio

Post Docs: AMANATIDIS Georgios, BIRMPAS Georgios, LAZOS Philip and REIFFENHAUSER Rebecca

PhD students: BARNABÒ Giorgio, BUCARELLI Maria Sofia, FUSCO Federico, GENTILI Michele, MARTINI Leonardo, MASTROPIETRO Andrea, MENGHINI Cristina and SICILIANO Federico

The group of Algorithms and Data Science performs theoretical and applied research in the areas of algorithms and data science. There is particular interest in 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.

Publications

Journal papers

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3.2.3 Artificial Intelligence and Knowledge Representation

Research lines:

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

Members: CARLUCCI AIELLO Luigia *(Former)*, DE GIACOMO Giuseppe (leader), LEMBO Domenico, LENZERINI Maurizio, LIBERATORE Paolo, NARDI Daniele, PATRIZI Fabio and ROSATI Riccardo

Post Docs: CIMA Gianluca, DI STASIO Antonio, LEPORE Lorenzo, PERELLI Giuseppe, RONCA Alessandro, RUZZI Marco, SANTARELLI Valerio and ZHU Shufang

PhD students: BRUNORI Damiano, CHIARIELLO Francesco, CIPOLLONE Roberto, CROCE Federico, FAVORITO Marco, FUGGITTI Francesco, NAMICI Manuel, PALUDO LICKS Gabriel, SCAFOGLIERI Federico and UMILI Elena

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 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.

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.

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3.2.4 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: CAPOBIANCO Roberto, GRISETTI Giorgio, IOCCHI Luca, NAPOLI Christian and NARDI Daniele (leader)

Post Docs: RICCIO Francesco

PhD students: ALBANI Dario *(Former)*, ALOISE Irvin, BRIGATO Lorenzo, CARBONE LORIO Carlos Salvador, CATACORA OCANA Jim Martin, DELLA CORTE Bartolomeo *(Former)*, FAWAKHERJI Mulham, FERRARELLI Paola, IMPEROLI Marco, SCHLEGEL Dominik, WANG Lun and YOUSSEF ALI

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 developments in sensor technology and robotics, is the ability to deal with manifold representations 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 language 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.

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3.2.5 Computer Networks and Pervasive Systems

Research lines:

- Blockchain Technologies
- Decentralized Applications
- Internet of Things
- Networks of Resource Constrained Devices
- Self-* Protocols and Systems
- Wireless and Sensor Networks

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

The miniaturization of electronic devices and the advancements in telecommunications, make it possible the realization of ubiquitous pervasive systems, i.e. systems in which information processing has been thoroughly and transparently integrated into everyday objects and activities. These systems are composed of heterogeneous tiny artefacts such as wireless sensor nodes, RFID and NFC tags and readers, mobile phones etc. Such devices are often constrained in their computational and energy resources and are often organized in networks that do not rely on wired infrastructures and that contribute to the realization of the Internet of Things (IoT).

The realization of such systems requires new solutions in the design of algorithms and protocols for wireless ad hoc networks connecting large numbers of devices. Such networks might be very large and operate in a highly dynamic environment: sensor nodes move, enter and exit the system and are prone to faults, while communication links are often noisy and unreliable. As a consequence, adopted solutions should be simple, efficient, and robust; in particular, since energy is usually provided by batteries, energy efficiency must always be considered as a primary goal. The scale and nature of pervasive systems requires networks able to react to unexpected events and to operate beyond the complete understanding and control of the designer and of the user. In fact, these systems should achieve an appropriate level of self-organization and integration to adapt to continuously changing environments and to cope with unforeseen faults.

Our research focuses on the design, analysis, experimentation and implementation of algorithms and protocols for the Internet of Things.

We are also interested in solving complex communications primitives such as service discovery and event-based data diffusion, with the final goal of characterizing sensors networks as a data storage and retrieval. In these context, interesting security and privacy issues emerge that due to the limited resources and the distributed nature of the applications, require the development of new techniques and algorithms. We complement our research with an extensive experimental work that is based on simulations (using network simulators such as NS2, OMNET++ and Shawn), and on test-beds (e.g., we run a permanent test-bed of wireless sensor network to monitor the ancient roman remains at the basement of DIAG and we have about 600 active tags to collect and analyze the so-called proximity graph, namely a graph in which nodes are users and there is a link between two nodes if there are in proximity).

More recently we have started a research activity on decentralized applications and the employment of blockchain technologies to support the development of a new distributed architectures beyond the classical client/server paradigm.

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3.2.6 Computer Vision, Computer Graphics, Deep Learning

Research lines:

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

Members: NTOUSKOS Valsamis, PIRRI Fiora (leader) and SCHAERF Marco

Post Docs: SANZARI Marta

PhD students: ALATI Edoardo, PUJA FRANCESCO

The Computer Vision, Computer Graphics, Deep Learning group is a multidisciplinary team of researchers that investigates several knowledge areas and apply them to scientific problems in many contexts. The team works on several topics related to Computer Vision and Graphics:

Visual Search — Visual search of relevant targets in the environment is a crucial robot skill. Our research group investigates this topic by proposing a number of frame- works for the execution monitor of a agent task (described in the next section), taking care of the agent attitude to visually searching the environment for targets involved in the task. Visual search is also relevant in the field of artificial Intelligence for robotics and find one of its best application in the task of recovering from a failure. Our works exploit deep reinforcement learning to acquire a com- mon sense scene structure and it takes advantage of a deep convolutional network to detect objects and relevant relations holding between them.

Visual Execution Monitoring — The execution and monitoring of high-level robot actions in a real environment can be concretely enhanced addressing the problem with an hybrid deterministic/nondeterministic state machine streaming perceptual information, strengthened by visual search and recognition. Our research line focuses on the great results of deep learning, which allow to strongly rely on visual perception, for both monitoring the state of the world in terms of preconditions and postconditions that hold before and after the execution of an action and using a search policy to either guide where to look at or to refocus in case of a failure.

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 Forecasting Network (AFN).

Memory and next step prediction in Long Short Time Memory Networks — Following the line of work presented in the above section we particularly placed much attention to the behavior of LSTMs in keeping past information through the various iterations. In the context of action forecasting this is a crucial step to address since the forecasting step is possible only if the relevant information are kept in memory. We also focused our attention on understanding the relation between the features of past sequences and future steps both mathematically and in the practically in the available datasets.

Scene Representation and Interpretation — In order to deal with real environment and complex tasks and problems, there is the necessity of having an optimized scene representation to deal with. This kind of representation needs to be at the same time parsimonious and full of information. Therefore, our research group investigates possible representations as Mental Maps, which exploits the semantic, geometrical and ... information kept by a semantic segmentation that includes only the elements that could be useful to the agent to achieve its task.

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 neural network approach via the use of several new architecture. Inspired from, first, Faster-RCNN network developed by Ren, Shaoqing, He, Kaiming, Girshick, Ross and Sun, Jian (2015) and, then, Mask-RCNN developed by He, Kaiming, Gkioxari, Georgia, Dollá r, Piotr, Girshick, Ross (2017), our research focused on developing new architectures by improving performances, computation time, capacity and multi-tasking properties.
Scene and Context Understanding — The problem of enabling an agent to perceive and understand the surrounding environment is not limited only to a correct representation via a semantic segmentation. A set of objects and a number of structural or contextual scene details can define a context. This information is crucial to infer some information but, even more, to disambiguate the increasing uncertianty that each prediction introduces in the prediction system. Therefore, our research group investigates the algorithms, both of classical machine learning and deep learning, to extract contexts from the analyzed data and allow big frameworks to operate correctly with an enriched knowledge of the world.

Augmented Reality — Within the context of our research activities, Augmented Reality is becoming a compelling technology mainly for the interactive 3D visualization. First, it was used in the context of archaeological sites on hand-held devices and for building of complex planning scenarios for robots, eliminating the need to model the dynamics of both the robot and the real environment as it would be required by whole simulation environments. Then, relevant applications in this field are related to the augmentation of real environments with additional elements. Our research on these topics is mainly focused on the use of generative models and, in particular, Generative Adversarial Models.

Dense Image Fusion, Meshing, 3D Surface Reconstruction — In the field of Object Reconstruction, a new approach is proposed for 3D modeling of articulated objects, specifically animals, using both components and component aspects. A component of an articulated object is defined here to be that part of it, which is only partially deformable. An aspect is defined as a view of the component from a specific vantage point. Aspects are fixed for an object component. Each aspect is modeled from a single image, using an inflation algorithm and the deformation paradigm. Then aspects are blended and merged together to form the whole component.

Gesture Recognition from 3D data — The problem of Human Primitives Recognition is investigated, in our research work, within Motion Capture sequences. In this con- text, we investigated methods based on Gaussian Process Latent Variable Models and Alignment Kernels. We propose a new discriminative latent variable model with back-constraints induced by the similarity of the original sequences. We com- pare the proposed method with methods based on Dynamic Time Warping and with V-GPDS models, which are able to model highly dimensional dynamical systems. Another line of work is to recognize human actions, starting from a 3D input data sequence, independently from the camera point of view and from the physical aspect of the person under examination. To face this problem, Kernelized Temporal Cut is used for segmenting the sequence and finding cut points among different actions. Then, a spatio-temporal manifold model is used for representing the time series data and a spatio-temporal alignment algorithm is introduced in order to find matches between action segments.

Terrain Traversability in Rescue Environments — 3D Terrain understanding and structure estimation is a crucial issue for robots navigating rescue scenarios. Unfortunately, large scale 3D point clouds provide no information about what is ground, and what is top, what can be surmounted and what can be not, what can be crossed, and what is too deep to be traversed. In this context, this research work mainly concentrated in providing methods for point cloud structuring which can lead to a definition of traversability cost maps.

3.2.7 Cybersecurity

Research lines:

- Data privacy and security
- Malware Analysis
- Security for cyber-physical systems
- Security governance
- Threat intelligence

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

Post Docs: ANGELINI Marco, D'ELIA Daniele Cono

PhD students: ARTUSO Fiorella, BARDHI Enkeleda, BORRELLO Pietro, BORZACCHIELLO Luca, BRIGATO Lorenzo, CARELLO Patrizia, CONSOLE Francesca, FERRACCI Serena, GERMANà Roberto, LAURENZA Giuseppe *(Former)*, MASSARELLI Luca, NICCHI Simone *(Former)* and TORTORELLI Andrea

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 compromise 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 underling 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.).

Binary similarity. Different works in literature afford the problem of binary similarity: given the binary code of two different functions they try to understand if these two binaries have been compiled from the same source. The problem has a large number of potential applications, but it is not trivial because the source code can be compiled with different compilers on different platforms, or the compiler can use different optimizations. We study how we can generalize this definition of similarity using deep learning. In particular, we aim at identifying semantic similarities among compiled functions to support malware analysis.

Blockchain. Blockchain is an emerging paradigm that allows to store data in a fully decentralized system guaranteeing data integrity and transparency in the data flow.

Actually, several technologies exists that allows 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 via model-based control-theoretical 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.

Evasive malware. Sandboxes are a staple of modern malware detection and analysis techniques. However, malware writers over the years have adapted their strategies in order to have malicious sample hide their true colors when executing in such analysis environments. Fingerprinting techniques are employed to detect distinctive features of sandboxing products or even better of the virtualization technologies they rely upon. We investigate how dynamic binary instrumentation can be used to detect evasive attempts by malware samples, and fake the results provided by the execution environment in order to give a sample the illusion that it is executing in a non-hostile environment, or in a very specific hardware and software configuration in the case of APT malware.

Information Extraction for Open Source Intelligence. Open-Source INTelligence (OSINT) is intelligence based on publicly available resources, such as news sites, blogs, forums, social networks, etc. In OSINT, the Web is the primary source of information, and extracting, structuring and interpreting such information are crucial problem in many application scenarios, like, for instance, security, market intelligence, or statistics. We study how to transform raw information crawled from the Web into actionable data, by coupling traditional information extraction approaches with the use of semantic technologies, which may help to automatize this process and to assign a precise structure and a clear semantic to the extracted data.

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.

Return Oriented Programming. Code reuse attacks are exploits in which an attacker can execute arbitrary code on a compromised machine without having to inject it in memory, as they achieve the intended behavior by joining fragments of code belonging to a legit installed software component. 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 be sometimes a cumbersome task even for security professionals due to the entanglements of ROP code, and frequently an offputting job for researchers. We are also exploring how code reuse can be employed in a defensive scenario, for instance to protect intellectual property in the context of code obfuscation and anti-piracy applications.

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 collective attestation problem by reducing it into a minimum consensus one and the results confirm the suitability of such 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.

Visual analytics. 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.

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.

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3.2.8 Data Management and Service-Oriented Computing

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: CARLUCCI AIELLO Luigia *(Former)*, CATARCI Tiziana, DE GIACOMO Giuseppe, LEMBO Domenico, LENZERINI Maurizio (leader), LEOTTA Francesco, MARRELLA Andrea, MECELLA Massimo, PATRIZI Fabio and ROSATI Riccardo

Post Docs: CIMA Gianluca, LEPORE Lorenzo and SANTARELLI Valerio

PhD students: AGOSTINELLI Simone, CROCE Federico, FERRO Lauren Stacey, NAMICI Manuel, SAPIO Francesco, SCAFOGLIERI Federico 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, now 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 ap- plications. 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 services 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.

Publications

Journal papers

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3.2.9 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: BALDONI Roberto (leader), BERALDI Roberto, BONOMI Silvia, CICIANI Bruno, DI LUNA Giuseppe Antonio and QUERZONI Leonardo

Post Docs: FARINA Giovanni

PhD students: LAURENZA Giuseppe *(Former)*

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 focusing, in particular, on algorithms for dynamic settings and algorithms for robust lattice agreement algorithms.
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 focused 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.

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

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Das S., Di Luna G. A., Flocchini P., Santoro N., Viglietta G., Yamashita M. "Oblivious permutations on the plane". In: *23rd International Conference On Principles Of Distributed Systems (opodis 2019)*, (volume: 153) (2020). DOI: 10.4230/LIPIcs.OPODIS.2019.24

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3.2.10 High Performance and Dependable Computing Systems

Research lines:

- Heterogeneous Computing
- High Performance Computing
- Multi-core Programming
- Multi-tier Architectures
- Non-blocking/Wait-Free Algorithms
- Operating Systems
- Parallel and Distributed Computing Platforms
- Performability Models
- Software Instrumentation and Compiling Techniques
- Software Reversibility on Non-Reversible Systems
- Transactional Systems
- Virtualization and Cloud Computing

Members: CICIANI Bruno (leader)

Post Docs: DI SANZO Pierangelo and PELLEGRINI Alessandro

PhD students: BACOCCO Duilio Luca, CARNA Stefano, CONOCI STEFANO, MAROTTA ROMOLO, PICCIONE Andrea and SILVESTRI Emiliano

The High Performance and Dependable Computing Systems research group research activities are focused on differentiated aspects of computing and service-oriented applications and platforms, spanning from theory to modeling, design and implementation. Significant results have been achieved in:

- system-level cyber security, with a special focus on speculative execution;
- operating systems and virtualization, with a special focus on innovative capabilities offered by modern operating systems;
- the definition of frameworks and protocols for dependability in large scale infrastructures, with particular attention to application contexts entailing manipulation of data within (atomic) distributed transactions;
- the design and implementation of high-performance computing with particular interest to discrete event simulation platforms conforming to both proprietary and standardized protocol stacks;
- the design and development of innovative operating system services oriented to support-high performance computing applications and data intensive ones;
- binary instrumentation to transparently inject non-functional, rather performance/reliability-oriented capabilities, within general applications;
- the design of techniques for improving energy-efficiency of applications deployed on massively-parallel machines;
- the design and/or exploitation of transactional memory paradigms, either software- or hardware-based;
- the design and implementation of transparent middleware-level software to enable software reversibility on top of non-reversible hardware, as a building block to

optimize execution of data-intensive applications and/or enable post-mortem reversible debugging;
- the definition and validation of accurate performance and dependability models for components/sub-systems forming the core of the aforementioned computing environments.

The vision characterizing the research of this group is based on a strong synergy between theoretical studies and design/development techniques aimed at bridging theory and practice by accurately assessing the viability of research results in environments and application contexts based on current technologies, and in those that can be foreseen via emerging technological trends. Up to now, various open source packages have been released as a concrete indication of the effectiveness of the aforementioned approach. Some of the publicly-released packages have been already adopted by other (foreign) research centers/industrial parties.

Several research challenges can be easily envisaged along the paths of Quality-of- Service (QoS) oriented design of systems, as well as the design of autonomic systems embedding self-properties aimed at ensuring/guaranteeing/achieving pre-determined performance and/or dependability levels. The container hosting and framing these challenges will include both traditional system organizations and innovative computing environments relying on systematic use of infrastructure virtualization approaches, such as cloud computing. Further, we target innovative programming models and paradigms, such as sequential/concurrent programming based on (a) transparent and automatic techniques supporting reverse computing schemes as a mean for maintaining causal consistency as well as guaranteeing fault tolerance and security, and to enable reversible/post-mortem debugging (b) transparent injection via instrumentation of non-functional logic within generic applications so as to guarantee the possibility to drive the execution of these applications while optimizing resource/energy usage as well as performance.

The group is constantly collaborating with University of Rome "Tor Vergata" (DICII department), University of L'Aquila, CNR (SAKS group).

Publications

Journal papers

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3.2.11 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: CATARCI Tiziana (leader), LEOTTA Francesco, MARRELLA Andrea, MECELLA Massimo, SANTUCCI Giuseppe and TEMPERINI Marco

Post Docs: ANGELINI Marco

PhD students: BLASILLI Graziano, FERRO Lauren Stacey and SAPIO Francesco

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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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: AVENALI Alessandro, CATALANO Giuseppe, CONTI Chiara, D'ADAMO Idiano, D'ALFONSO Tiziana, DANGELICO Rosa Maria, DARAIO Cinzia, DI PILLO Francesca, FRACCASCIA Luca, MARZANO Riccardo, MATTEUCCI Giorgio, NASTASI Alberto (leader), NONINO Fabio, REVERBERI Pierfrancesco and SESTINI Roberta

Post Docs: ANNARELLI Alessandro, PALOMBI Giulia and VONA Luigi

PhD students: GIAGNORIO Mirko, GREGORI Martina, PETITTI Federico and SCHIAROLI Valerio

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

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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 and SASSANO Antonio (leader)

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

Bruni R., Daraio C., Aureli D. "Imputation techniques for the reconstruction of missing interconnected data from higher Educational Institutions". In: *Knowledge-based Systems*, (2020). DOI: 10.1016/j.knosys.2020.106512

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Bianchi Gianpiero, Bruni Renato, Daraio Cinzia, Laureti Palma Antonio, Perani Giulio, Scalfati Francesco "Exploring the Potentialities of Automatic Extraction of University Webometric Information". In: *Journal Of Data And Information Science*, (volume: 5) (2020), pp. 43 - 55. DOI: 10.2478/jdis-2020-0040

Bruni R., Catalano G., Daraio C., Gregori M., Moed H. F. "Studying the heterogeneity of European higher education institutions". In: *Scientometrics*, (volume: 125) (2020), pp. 1117 - 1144. DOI: 10.1007/s11192-020-03717-w

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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: DE SANTIS Alberto, DE SANTIS Marianna, DI PILLO Gianni, FACCHINEI Francisco (leader), LIUZZI Giampaolo, LUCIDI Stefano, PALAGI Laura, ROMA Massimo and SAGRATELLA Simone

PhD students: BATTISTA Federico, BORESTA Marco, CALAMITA Alice, CROELLA Anna Livia, D'AGOSTINO Danny, D'ONOFRIO Federico, DI STEFANO Andrea, GIOVANNELLI Tommaso, MEROLLA Davide, MONACI Marta, PINTO Diego Maria, ROMITO Francesco, SECCIA Ruggiero and TRONCI Edoardo Maria

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.

Moreover, as a spin-off of the activity carried out in applied optimization, the company ACTOR (Analytics, Control Technologies and Operations Research) has been founded. ACTOR is participated by Sapienza University, by researchers of the Department and by the private company ACT Solutions. The main aim of ACTOR is to develop and commercialize advanced optimization models and methods to be employed in the production and management of goods and services.

Publications

Journal papers

Seccia Ruggiero, Boresta Marco, Fusco Federico, Tronci Edoardo, Di Gemma Emanuele, Palagi Laura, Mangone Massimiliano, Agostini Francesco, Bernetti Andrea, Santilli Valter, Damiani Carlo, Goffredo Michela, Franceschini Marco "Data of patients undergoing rehabilitation programs". In: *Data In Brief*, (volume: 30) (2020). DOI: 10.1016/j.dib.2020.105419

Avancini A., Pala V., Trestini I., Tregnago D., Mariani L., Sieri S., Krogh V., Boresta M., Milella M., Pilotto S., Lanza M. "Exercise levels and preferences in cancer patients: A cross-sectional study". In: *International Journal Of Environmental Research And Public Health*, (volume: 17) (2020), pp. 1 - 22. DOI: 10.3390/ijerph17155351

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De Santis Marianna, Eichfelder Gabriele, Niebling Julia, Rocktäschel Stefan "Solving Multiobjective Mixed Integer Convex Optimization Problems". In: *Siam Journal On Optimization*, (volume: 30) (2020), pp. 3122 - 3145. DOI: 10.1137/19M1264709

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3.5 Systems and Control Engineering

3.5.1 Networked Systems

Research lines:

- Control of Networks
- Control under Communication Constraints
- Modeling, Filtering and Optimal Control of Communication Networks
- Remote Control

Members: DELLI PRISCOLI Francesco (leader), DI GIORGIO Alessandro, ISIDORI Alberto and PIETRABISSA Antonio (leader)

Post Docs: GIUSEPPI Alessandro, LIBERATI Francesco and PANFILI Martina

PhD students: DE SANTIS Emanuele, DONSANTE Manuel, GERMANÀ Roberto, ORNATELLI Antonio and TORTORELLI Andrea

The Networked Systems research group, led by Prof. Francesco Delli Priscoli and Prof. Antonio Pietrabissa, aims at developing control methodologies in or over 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.

The Networked Systems research group has developed thanks to the successful participation in National and European research projects carried on together with major European ICT and energy players.
The networked systems area supports a Future Internet vision (in particular, the Networked Systems research group participated to the large FI-WARE EU project concerning the Future Internet technology foundation) foreseeing a technology independent distributed framework including coordinated advanced control algorithms (utilizing methodologies such as reinforcement learning for multi-agent systems, game theory, optimal control, model predictive control and robust control). These algorithms, on the basis of homogeneous integrated metadata (derived from properly selected heterogeneous information related to the present network and user status, converted to metadata and aggregated in a context-aware fashion), make consistent decisions (which are eventually actuated in the networks) concerning the management of network resources and of network contents/services, aiming at maximizing resource exploitation while satisfying users in terms of Quality of Experience expectations (related to Quality of Service, security and mobility requirements).
To deal with the above-mentioned vision, the Networked Systems area deals with the following key enablers: model-free learning, multi-agent systems with minimum coordination, cross-layering/cross-network optimization, context awareness, data fusion, decision support systems.
In the framework of recent and in-progress projects, the above-mentioned vision has been applied in the following areas: home network speed enhancement up to Gbps, optimization

of hybrid *ad hoc* and satellite networks, resource management for telecommunication and energy distribution networks (smart grids), demand side management for planning electric utilities, smart grids for supporting fully electrical vehicles, content management for peer-to-peer television, protection of critical infrastructures, total airport security, embedded system security/privacy/dependability, remote diagnosis and management of cardiovascular diseases, intermodal mobility solutions for people and goods, space assets for demining assistance, wireless cognitive sensor networks.
In 2013, the Sapienza Start Up Ares2t was funded by members of the Networked System group on the ground of the researches in the field of smart grids.

Recent and on-going projects

- 5G-SOLUTIONS, 5G Solutions for European Citizens (managed by CRAT), June 2019-May 2022, EU H2020-ICT-2019 Project.
- SESAME, Smart European Space Access thru Modern Exploitation of Data Science (managed by CRAT), January 2015 - December 2022, EU H2020-SPACE-16-TEC-2018 Project.
- 5G-ALLSTAR, 5G AgiLe and fLexible integration of SaTellite And cellular (managed by CRAT), July 2018-June 2021, H2020-EUK2018 Project.
- PROMETEO, Protezione di reti elettriche di potenza da attacchi cyber-fisici mediante strategie di controllo, progetto di Ateneo, prot. RM11715C7EFAF857.

Publications

Journal papers

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Giuseppi Alessandro, Pietrabissa Antonio "Wardrop Equilibrium in Discrete-Time Selfish Routing with Time-Varying Bounded Delays". In: *Ieee Transactions On Automatic Control*, (2020), pp. 1 - 12. DOI: 10.1109/TAC.2020.2981906

Conference proceedings

Kim Junhyeong, Casati Guido, Pietrabissa Antonio, Giuseppi Alessandro, Calvanese Strinati Emilio, Cassiau Nicolas, Noh Gosan, Chung Heesang, Kim Ilgyu, Thary Marjorie, Houssin Jean-michel, Pigni Federico, Colombero Sylvain, Dal Zotto Pierre, Raschkowski Leszek, Jaeckel Stephan "5G-ALLSTAR: An Integrated Satellite-Cellular System for 5G and Beyond". In: *Procedeengs Of The 2020 Ieee Wireless Communications And Networking Conference Workshops (wcncw)*, (2020), pp. 1 - 6. DOI: 10.1109/WCNCW48565.2020.9124751

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3.5.2 Nonlinear Systems and Control

Research lines:

- Delay Systems
- Discrete-time and Sampled Data Systems
- Epidemic modeling and control
- Hybrid Systems
- Multi-Agent and Multi Robot Systems
- Optimal Control and Stochastic Systems
- Optimal control for resource management
- Systems analysis and control

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

Post Docs: D'ANGELO Massimiliano

PhD students: ELOBAID Mohamed and MORESCHINI Alessio

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

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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 (leader), LANARI Leonardo, ORIOLO Giuseppe and VENDITTELLI Marilena

Post Docs: AL KHUDIR Khaled, CEFALO Massimo, FERRO Marco, GAZ Claudio Roberto, KHATIB Maram, MODUGNO Valerio and SCIANCA Nicola

PhD students: BARROS CARLOS Barbara, BELVEDERE Tommaso, CAPOTONDI Marco, CIPRIANO Michele, FERRARI Paolo, SMALDONE Filippo Maria, TARANTOS Spyridon, TURRISI Giulio 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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