

DIAG - Research areas

Biomedical Engineering

Economics

Engineering in Computer Science

Management Engineering

Operations Research

Systems and Control Engineering

Dipartimento di Ingegneria informatica automatica e gestionale Antonio Ruberti

Via Ariosto 25, 00185 Roma

www.diag.uniroma1.it

Research Report 2017

Dipartimento di Ingegneria informatica automatica e gestionale Antonio Ruberti



DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI

Research Report 2017



SAPIENZA
UNIVERSITÀ DI ROMA

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

Research report 2017

Dipartimento di Ingegneria informatica, automatica e gestionale Antonio Ruberti

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Contents

1	Introduction	1
2	General Information	2
2.1	Location	2
2.2	Facilities	2
2.3	People	6
2.4	Doctoral Programs	8
2.5	Visiting Scientists and Scholars	12
2.6	Seminars and Workshops	13
2.7	Honours and Awards	15
2.8	Contracts	16
3	Research Areas	21
3.1	Biomedical Engineering	22
3.1.1	Bioengineering and Bioinformatics	22
3.2	Economics	24
3.2.1	Innovation, Internationalization and the Environment	24
3.3	Engineering in Computer Science	27
3.3.1	Algorithm Design and Engineering	27
3.3.2	Algorithms and Data Science	30
3.3.3	Artificial Intelligence and Knowledge Representation	31
3.3.4	Artificial Intelligence and Robotics	35
3.3.5	Computer Networks and Pervasive Systems	37
3.3.6	Computer Vision, Computer Graphics, and Perception	39
3.3.7	Cybersecurity	43
3.3.8	Data Management and Service-Oriented Computing	47
3.3.9	Distributed Systems	51
3.3.10	High Performance and Dependable Computing Systems	53
3.3.11	Human-Computer Interaction	55
3.4	Management Engineering	57
3.4.1	Industrial Organization and Management	57
3.5	Operations Research	60
3.5.1	Combinatorial Optimization	60
3.5.2	Continuous Optimization	62
3.6	Systems and Control Engineering	65
3.6.1	Networked Systems	65
3.6.2	Nonlinear Systems and Control	67
3.6.3	Robotics	69
4	Publications	71

1 Introduction

The present document is a report about the research activity carried out in 2017 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 2017 consists of 23 full professors, 26 associate professors, and 20 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 2017. A collection of the Department’s publications for 2017 is reported in Section 4.

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

The library was first established in 1970 at the Istituto di Automatica. In 2007, the library moved with the department to its current location in Via Ariosto, and there are two reading rooms available for students. Its holdings contain approximately 11,000 books and conference proceedings, 392 journal subscriptions (94 of which are currently active). The Library complements its collection with user access to all the key online resources, bibliographic databases, and scientific content discovery services. The library facilities are also available to students and faculty of other departments and universities.

In 2011, the department library began to acquire books in electronic format. The library now has over 500 ebook titles available, accessible both on the library website and in the central online catalog. Several eReaders have been purchased for student use, and the library is currently testing the use of the eReaders as a course-related-content delivery system for articles, references and resources relevant to courses taught at the Department.

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.

Co-Heads: Laura ASTOLFI and Febo CINCOTTI

Data And Service Integration Laboratory (DASILab)

Via Ariosto 25 - room 213, wing B2

The laboratory is devoted to the development of software research prototypes for service-based and data-integration systems.

Web: <http://www.diag.uniroma1.it/dasilab>

Head: Maurizio LENZERINI

Organization: Massimo MECELLA

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>

Co-Heads: Paolo DI GIAMBERARDINO and Marco TEMPERINI

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: Roberto BALDONI

Network Control Laboratory

Via Ariosto 25 - room 215, 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://labreti.ing.uniroma1.it/>

Head: Francesco DELLI PRISCOLI

DIAG Robotics Lab

Via Ariosto 25 - basement

The laboratory is devoted to the development and experimental validation of advanced planning and control techniques for industrial and service robots.

Web: <http://www.diag.uniroma1.it/~labrob>

Head: Giuseppe ORIOLO

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

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: <http://www.diag.uniroma1.it/~ficarola/wsn-group/>

Head: Andrea VITALETTI

Additional information on the research laboratories may be found at

<http://www.diag.uniroma1.it/en/node/60/research-laboratories>.

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.

Person in charge: Umberto NANNI.

PC and Workstations Laboratory Paolo Ercoli for advanced courses

Via Eudossiana 18, Roma.

About 75 PC and workstations are available for the graduate teaching.

Person in charge: Umberto NANNI.

Management Engineering Laboratory

Via Ariosto 25 - room A122 and A123, wing A1

11 PCs are available. The laboratory is devoted to thesis students for the development of mathematical models and solution algorithms for Management Engineering problems.

Web: <http://www.diag.uniroma1.it/~labinggest>

Person in charge: Massimo ROMA

Additional information on educational laboratories may be found at <http://www.diag.uniroma1.it/en/node/59/teaching-laboratories>.

2.3 People

Head of Department Alberto MARCHETTI SPACCAMELA

Administration Head Venerino FILOSA

Professors

Giorgio AUSIELLO (emeritus)
 Roberto BALDONI
 Stefano BATTILOTTI
 Luigia CARLUCCI AIELLO (emeritus)
 Giuseppe CATALANO
 Tiziana CATARCI
 Bruno CICIANI
 Giuseppe DE GIACOMO
 Alessandro DE LUCA
 Francesco DELLI PRISCOLI
 Gianni DI PILLO (emeritus)
 Camil DEMETRESCU
 Francisco FACCHINEI
 Alberto ISIDORI (emeritus)
 Maurizio LENZERINI
 Stefano LEONARDI
 Claudio LEPORELLI (emeritus)
 Stefano LUCIDI
 Alberto MARCHETTI SPACCAMELA
 Salvatore MONACO
 Umberto NANNI
 Daniele NARDI
 Alberto NASTASI
 Giuseppe ORIOLO
 Fiora PIRRI
 Riccardo ROSATI
 Francesca SANNA RANDACCIO
 Antonio SASSANO
 Marco SCHAEFER

Associate professors

Aris ANAGNOSTOPOULOS
 Alessandro AVENALI
 Luca BECCHETTI
 Luca BENVENUTI
 Barbara CAPUTO
 Ioannis CHATZIGIANNAKIS
 Febo CINCOTTI
 Fabrizio D'AMORE
 Rosa Maria DANGELICO

Cinzia DARAIO
 Alberto DE SANTIS
 Lorenzo FARINA
 Luca IOCCHI
 Domenico LAISE
 Leonardo LANARI
 Domenico LEMBO
 Paolo LIBERATORE
 Massimo MECELLA
 Fabio NONINO
 Laura PALAGI
 Francesco QUAGLIA (up to May 2017)
 Pierfrancesco REVERBERI
 Massimo ROMA
 Silvio SALZA
 Giuseppe SANTUCCI
 Roberta SESTINI
 Marco TEMPERINI

Assistant professors (ricercatori)

Laura ASTOLFI
 Roberto BERARDI
 Silvia BONOMI
 Renato BRUNI
 Claudia CALIFANO
 Tiziana D'ALFONSO
 Marianna DE SANTIS (since March 2017)
 Paolo DI GIAMBERARDINO
 Alessandro DI GIORGIO (since January 2017)
 Mario GIANNI (up to September 2017)
 Giorgio GRISETTI
 Daniela IACOVIELLO
 Riccardo LAZZERETTI (since March 2017)
 Valsamis NTOUSKOS (since January 2017)
 Fabio PATRIZI
 Antonio PIETRABISSA
 Alberto PRETTO
 Leonardo QUERZONI
 Tatiana TOMMASI (up to September 2017)
 Marilena VENDITTELLI
 Andrea VITALETTI

*Post Doc (research associates)
and research assistants*

Marco ANGELINI
Leonardo ANIELLO
Graziella BONANNO
Emanuele BORZI
Silvia CANALE
Massimo CEFALO
Angela CIARAMIDARO
Claudio CICCOTELLI
Marco COGNETTI
Chiara CONTI
Emilio COPPA
Daniele Cono D'ELIA
Antonella DEL POZZO
Pierangelo DI SANZO
Adriano FAZZONE
Andrea FIASCHETTI
Claudio GAZ
María Teresa LÁZARO
Francesco LEOTTA
Lorenzo LEPORE
Francesco LIBERATI
Emanuele MAGRINI
Andrea MARRELLA
Valerio MODUGNO
Luca MONTANARI
Martina PANFILI
Alessandro PELLEGRINI
Manuela PETTI
Andrea RIBICHINI
Giacomo RONCONI
Marco RUZZI

Simone SAGRATELLA
Valerio SANTARELLI
Vincenzo SURACI
Domenico Fabio SAVO
Chris SCHWIEGELSHOHN
Jlenia TOPPI
Letterio ZUCCARO

Administration staff

Flavia CAGNIZI
Antonella CANCELLIERI
Antonietta CANGELLI
Ugo CINELLI
Sabrina GIAMPAOLETTI
Domenico MACARI
Giuseppina MELITA
Tiziana VALENTINI
Maria Pia VANDILLI
Laura VESCOVI

Technical staff

Andrea DORI
Luciano GRANDI
Marcello PANI
Tiziana TONI

Auxiliary services

Antonio SIMEONI

Library

Roberta PROIETTI SEMPRONI
Antonietta ZUCCONI

2.4 Doctoral Programs

DIAG hosts the PhD programs in *Engineering in Computer Science* and in *Automatica, Bio-engineering and Operations Research*.

Engineering in Computer Science

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, computer networks and security.

PhD Students

XXIX course

Federico FERRI
Mara SORELLA

XXX course

Valentina FRANZONI
Federico LOMBARDI
Federico NARDI
Francesco RICCIO
Manuel Alejandro RUIZ GARCIA
Daniele UCCI
Andrea VANZO

XXXI course

Fabio ANGELETTI
Fabio Maria CARLUCCI
Davide CINGOLANI
Simone ECONOMO
Mauro IANNI
Marco IMPEROLI
Fabrizio NATOLA
Ciro POTENA
Marta SANZARI
Daniele SORA
Ali YOUSSEF

XXXII course

Dario ALBANI
Gianluca CIMA

Bartolomeo DELLA CORTE

Paola FERRARELLI
Valentina GREGORI
Giuseppe LAURENZA
Massimiliano MANCINI
Romolo MAROTTA
Nizar MASSOUH
Francesco PUJA
Dominik SCHLEGEL
Mahmoud SHARF
Lun WANG

XXXIII course

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

PhD thesis completed in 2017

Mohammad ABU SNOBER

Towards a Collaborative Context-Aware Offloading Scheme in Mobile Cloud Computing

Advisor: Roberto BERALDI

Noor Aldeen ALAWAD

Network-Aware Recommendations in Online Social Networks

Advisor: Stefano LEONARDI

Marco ANGELINI

Predictive Visual Analytics: dealing with Situation Awareness, Prediction and Forecasting

Advisor: Giuseppe SANTUCCI

Davide AVERSA

Smart Pathfinding: Extending Pathfinding with Agent Capabilities

Advisor: STAVROS VASSOS

Taigo Maria BONANNI

A General Approach to Map Merging on Pose Graphs

Advisor: Giorgio GRISETTI

Roberto CAPOBIANCO

Interactive Generation and Learning of Semantic-Driven Robot Behaviors

Advisor: Daniele NARDI

Claudio CICCOTELLI

Practical Fault Detection and Diagnosis in Data Centers

Advisor: Leonardo QUERZONI

Marco CONSOLE

Ontology-based Data Quality: Principles, Methods, and Algorithms

Advisor: Maurizio LENZERINI

Antonella DEL POZZO

Building Distributed Computing Abstractions in the Presence of Mobile Byzantine Failures

Advisor: Silvia BONOMI

Maurilio DI CICCO

Model Learning for Mobile Robots

Advisor: Giorgio GRISETTI

Angela DI IORIO

Know Thyself: Engineering Workflows for Provenance Self-Aware System

Advisor: Marco SCHAERF

Adriano FAZZONE

Algorithms for Organizing Human Experts

Advisor: Stefano LEONARDI

Lorenzo LEPORE

Metamodeling and metaquerying in OWL 2 QL: semantics and algorithms

Advisor: Maurizio LENZERINI

Paoli MARIO

The Energy Problem in Resource Constrained Wireless Networks

Advisor: Andrea VITALETTI

Reem ATASSI

Recommendation for Groups, Tourist Itineraries, Social Activities

Advisor: Aris ANAGNOSTOPOULOS

Mohammad SALAH UDDIN

Multi-Robot Systems: From Grounding to Physical Execution. A Knowledge-based Approach

Advisor: Mario GIANNI

Jacopo SERAFIN

Using Extended Measurements and Geometric Features for Robust Long-Term Localization and Mapping

Advisor: Giorgio GRISSETTI

Annalisa TERRACINA

Combining Virtual Learning Environments and Intelligent Pedagogical Agents for a New Approach to Classroom Lessons

Advisor: Massimo MECELLA

Automatic Control, Bioengineering and Operations Research

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**XXIX course*

Laura D'ORSI
Maryam SALAMI

Mattia MATTIONI
Anna MELCHIORI
Gianluca MORGANTI
Marco VIOLA

XXX course

Lavinia AMOROSI
Alessandra ANZOLIN
Gabriele BUONDONNO
Andrea CALICIOTTI
Stefano CASCHERA
Federico Cimorelli
Stefano FOGLIETTA
Nicolò GIONFRA
Marwa HASSAN
Matteo MEKHAIL
Giacomo NAPOLI
Lorenzo RICCIARDI CELSI
Fabio SCIAMANNINI

XXXII course

Maria Laura ACETO
Tommaso COLOMBO
Massimiliano D'ANGELO
Eduardo FERREIRA FRANCO
Alessandro GIUSEPPI
Giorgio GRANI
Mohammed HAYMAN SALIH
Maram KHATIB
Maria Grazia PUXEDDU
Nicola SCIANCA

XXXI course

Khaled AL KHUDIR
Matilde BERTOLI
Stefano BERTULETTI
Emma COLAMARINO
Daniele DE SIMONE
Marco FERRO
Robinson GUACHI
Marianna INGLESE
Federico LISI
Ludovica MACCARRONE
Serena MANTOVANI

XXXIII course

Yuri ANTONACCI
Barbara BARROS CARLOS
Francesco CURIA
Danny D'AGOSTINO
Paolo FERRARI
Tommaso GIOVANNELLI
Alessio MORESCHINI
Antonio ORNATELLI
Francesco ROMITO
Mirko ROSSI
Ruggiero SECCIA
Andrea TORTORELLI

PhD theses completed in 2017

Gabriele BUONDONNO

Numerical Solutions for Design and Dynamic Control of Compliant Robots

Advisor: Alessandro DE LUCA

Andrea CRISTOFARI

Large-Scale Optimization: New Active-Set Methods and Application in Unsupervised Learning

Advisor: Stefano LUCIDI

Michela DI LULLO

Optimization of Generation and Transmission Topologies in Bulk Power Systems

Advisor: Giovanni FELICI

Dario Giuseppe FERRIERO

Personalized Assisted Human Machine Interface

Advisor: Antonio PIETRABISSA

Raffaele GAMBUTI

Accurate Vehicle Positioning and Multimodal Journey Planning for New Smart Mobility Scenarios

Advisor: Francesco DELLI PRISCOLI

Giacomo LANZA

Service Network Design Problem with Quality Targets and Stochastic Travel Time: New Model and Algorithm

Advisor: Nicoletta RICCIARDI

Valerio MODUGNO

Learning Safe Controllers for Motion Generation in Redundant Robots

Advisor: Giuseppe ORIOLO

2.5 Visiting Scientists and Scholars

DIAG hosts visiting scientists and scholars from all over the world. Here we list the visitors that spent at least one month at DIAG during 2017.

Seth HUTCHINSON, University of Illinois at Urbana-Champaign, USA, visiting professor, June-July 2017.

Antonio FRANCHI, LAAS-CNRS Toulouse, France, visiting professor, May 2017.

Yves LESPÉRANCE, York University, Toronto, ON, Canada, May-September and December-January 2017.

Sean LUKE, George Mason University, Fairfax, VA, USA, January-June 2017.

Irene MAVROMMATI, Hellenic Open University, Greece, September-October 2017.

Khuzaima DAUDJEE, University of Waterloo, Waterloo, ON, Canada, September-October 2017.

Leopold SIMAR, Université catholique de Louvain, Belgium, October-November 2017.

2.6 Seminars and Workshops

Many scientists are invited to deliver seminars at DIAG. Below we report the list of seminars for the year 2016, in chronological order. We also report the workshops organized at DIAG.

- December 20, 2017, Alessandro Fantoni, Instituto Politécnico de Lisboa: *Amorphous silicon photonics devices*.
- December 13, 2017, Cosimo Spera, BeeBell, Data Science SaltGrid: *Could technology help democracy? Using Blockchain to eliminate fake news*.
- December 4, 2017, Patricia Laurens & Antoine Schoen, ESIEE Paris (Université Paris-Est): *Analysing the R&D of big companies: data challenges and relevant policy issues*.
- November 8, 2017, Nikos Parotsidis, University of Rome Tor Vergata: *Decremental single-source reachability and strongly connected components*.
- October 24, 2017, Gabriel A. Wainer, Carleton University, ON, Canada: *Simulation everywhere*.
- October 23, 2017, Philippe Toint Université de Namur, Namur, Belgique: *High-order optimality in nonlinear optimization: necessary conditions and a conceptual approach of evaluation complexity*.
- October 23, 2017, Sylvain Sorin, Université Pierre et Marie Curie Paris, France: *Composite games: strategies, equilibria and dynamics*.
- October 19, 2017, Stephane Caron, CNRS-University of Montpellier LIRMM, France: *Pendular models for walking over rough terrains*.
- October 16, 2017, Mubarak Shah, Univ. of Central Florida, FL, USA: *Solving Semantic Segmentation: precision matrix, knowledge-based rules and Generator Adversarial Network (GAN)*.

- October 12, 2017, Chris Schwiegelsohn, Sapienza University of Rome: *On the local structure of stable clustering instances.*
- September 28, 2017, Randy Goebel (U. Alberta) & David Israel (SRI): *Distinguished lecture in AI.*
- September 14, 2017, Khuzaima Daudjee, University of Waterloo, ON, Canada: *Learning to cache through predictive execution.*
- September 12, 2017, Sean Ryan Fanello, PerceptiveIO, Inc.: *Low compute and fully parallel Computer Vision with HashMatch.*
- September 11, 2017, Camil Demetrescu, Sapienza University of Rome: *Scalable and secure software: new and old challenges in programming languages.*
- September 11, 2017, Domenico Lembo, Sapienza University of Rome: *Data Integration: an ontology-based perspective.*
- August 31, 2017, Tommaso Colombo, Sapienza University of Rome: *Recurrent Neural Networks: why do LSTM networks perform so well in time series prediction?*
- August 31, 2017, Ludovica Maccarrone, Sapienza University of Rome: *A new grey-box approach to solve the workforce scheduling problem in complex manufacturing and logistic contexts.*
- July 27, 2017, Marianna De Santis, Sapienza University of Rome: *A dual step for improving alternating augmented lagrangian methods for semidefinite programming.*
- July 27, 2017, Giorgio Grani, Sapienza University of Rome: *A heuristic method to solve the challenging Sales Based Integer Program for Network Airlines Revenue Management.*
- July 4, 2017, Graziella Bonanno, Sapienza University of Rome: *Measuring the efficiency of Italian airports: how to counter unexpected shocks.*
- July 4, 2017, Chiara Conti, Sapienza University of Rome: *Transition towards a green economy in Europe: innovation and knowledge integration in the renewable energy sector.*
- July 4, 2017, Riccardo Marzano, Politecnico di Milano: *The internationalization of state owned enterprises and the moderating role of varieties of capitalism.*
- July 5, 2017, Francesco Lissoni, Université de Bordeaux, France, and Bocconi University: *Patent data: Where do they come from? What are they good for?*
- July 5, 2017, Gianluca Tarasconi, Bocconi University: *The wealth of PatStat: document tracking in the Worldwide Patent Statistical Database.*
- May 29, 2017, Giliberto Capano, Scuola Normale Superiore, Institute for Humanities and Social Science, Florence, Italy: *Explaining performance of governance reforms in higher education. A systematic assessment in a comparative perspective.*

- May 24, 2017, Silvio Lattanzi, Google Research: *Consistent K-Clustering*.
- May 17, 2017, Romeo Ortega, Laboratoire de Signaux et Systèmes (SUPELEC), Paris, France: *PID Passivity-Based Control: application to energy and mechanical systems*.
- May 12, 2017, Leo Liberti, CNRS LIX École Polytechnique: *On the approximate solution of large dense Linear Programs*.
- April 28, 2017, Marlon Dumas, University of Tartu, Estonia: *Predictive monitoring of business processes*.
- April 27, 2017, Patrick Llerena, University of Strasbourg, France: *Science policy as a prerequisite of industrial policy*.
- April 13, 2017, Claudia Biancotti, Banca d'Italia: *Cyber attacks: preliminary evidence from the Bank of Italy's business surveys*.
- April 10, 2017, Alessio Moneta, Scuola Superiore Sant'Anna Pisa, Italy: *Data-driven causal search: limits and possibilities*.
- February 13, 2017, Emanuele Rodolà, Università della Svizzera Italiana, Lugano, Switzerland: *Spectral approaches to partial deformable shape matching*.
- February 2, 2017, Riccardo Lazzeretti, Sapienza University of Rome: *Signal processing in the encrypted domain for privacy preserving applications*.
- January 26, 2017, Maria-Isabel Sanchez-Segura, Carlos III Technical University of Madrid: *Da Vinci Talents and the Dynamics of Creativity: discovering the genius inside yourself*.
- January 24, 2017, BSLab-SYDIC International Workshop: *Model-based Governance for Smart Organizational Future*.
- January 12, 2017, Roberto Giacobazzi, Università di Verona: *Obscuring code – Towards systematic code obfuscation*.

2.7 Honours and Awards

- Maurizio Lenzerini was nominated AAAI Fellow (2017).

The following papers were awarded:

- Pierluigi Plebani, Andrea Marrella, Massimo Mecella, Marouan Mizmizi, Barbara Pernici: *Multi-party Business Process Resilience By-Design: A Data-Centric Perspective*, CAiSE 2017: 110-124, Best Paper Award.

- Chiara Conti, Maria Luisa Mancusi, Francesca Sanna-Randaccio, Roberta Sestini, Elena Verdolini: *Transition Towards a Green Economy in Europe: Innovation and Knowledge Integration in the Renewable Energy Sector*, Best Paper Award, 6th European Conference on Corporate R&D and Innovation (CONCORDi 2017).
- Roberto Baldoni, Roberto Beraldi, Vivien Quéma, Leonardo Querzoni, and Sara Tucci Piergiovanni. *Tera: Topic-based Event Routing for Peer-to-peer Architectures*. Test of Time Award, 11th International Conference on Distributed Event Based Systems. 2017.
- Alessandro De Luca received the *Mechanism and Machine Theory 2017 Award for Excellence* for the article *An Atlas of Physical Human-Robot Interaction* (published in 2008), as one of the top 10 most cited papers since journal publication.
- Francesco Romito: Winner of the *Generalization-based Contest in Global Optimization (GENOPT 2017)*, 11th Learning and Intelligent Optimization Conference (LION 11). 2017.

2.8 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.

Contracts with the European Union (EU)

- H2020 € 719.215, COMANOID - Multi-contact Collaborative Humanoids in Aircraft Manufacturing, G. Oriolo, ending 31-12-2018
- H2020 MSCA € 126,000, 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, F. Cincotti, ending 31-12-2021
- FP7-CP € 116.500, FLEXSIGHT - European Clearing House for Open Robotics Development Plus Plus, D. Nardi/A.Pretto, ending 30-09-2018
- H2020 MSCA € 207,000, FIRST - virtual Factories: Interoperation supporting business innovation, M. Mecella, ending 31-12-2020
- H2020 € 366.750, FLOURISH - Aerial Data Collection and Analysis, and Automated Ground Intervention for Precision Farming, D. Nardi, ending 31-08-2018
- DG-HOME € 125.214, PRIDE - Profiling Relations In Drug Trafficking in Europe, U. Nanni, ending 30-11-2017

- FP7-CP € 66.690, RISIS - Research infrastructure for research and innovation policy studies, C. Daraio, ending 31-12-2017
- ERC-STG € 1.496.277, RoboExNovo - Robots learning about objects from externalized knowledge sources, B. Caputo, ending 31-05-2019
- H2020 € 132.500, ROCKEU2 - Robotics Coordination Action for Europe Two, D. Nardi, ending 31-01-2018
- H2020 € 180.277, SAT-STABILIS - Nonlinear Sampled-data Attitude Stabilization of Underactuated Spacecraft, S. Monaco, ending 30-09-2017
- H2020 € 300,000, SCIROC - European Robotics League plus Smart Cities Robot Competitions, D. Nardi, 31-01-2022
- H2020 € 993.750, SECONDHANDS - SecondHands: A Robot Assistant For Industrial Maintenance Tasks, F. Pirri, ending 30-04-2020
- H2020 € 507.500, SYMPLEXITY - Symbiotic Human-Robot Solutions for Complex Surface Finishing Operations, A. De Luca, ending 31-12-2018
- FP7-CP € 753.968, TRADR - Long-Term Human-Robot Teaming for Robot-Assisted Disaster Response, F. Pirri, ending 31-12-2017
- CIP € 212.200, VOICE - Virtual Open Incubation Ecosystem, M. Mecella, ending 31-08-2017

Contracts with non-EU Institutions

- SNF (Fond National Suisse de la Recherche Scientifique) € 215.670, MEGANE-PRO - Myo-Electricity, Gaze and Artificial-intelligence for Neurocognitive Examination & Prosthetics, B. Caputo, 31-01-2019

Contracts with Italian Institutions

- CHIST-ERA € 357.570, ALOOF - Autonomous Learning of the Meaning of Objects, B. Caputo, ending 30-9-2017
- CHIST-ERA € 343.000, COACHES - Cooperative Autonomous robots in Complex and Humans EnvironmentS, L. Iocchi, ending 30-9-2017
- FIRB 2013 Futuro in Ricerca € 263,845, Stima della connettività inter-soggetto da registrazioni simultanee dell'attività neuroelettrica ed autonoma come strumento innovativo per lo studio dei meccanismi di interazione sociale nell'uomo, L. Astolfi, ending 14-03-2018
- Regione Lazio € 193.718, IncontraRicerca: un portale per favorire l'incontro tra la ricerca e le applicazioni, A. Marchetti Spaccamela, ending 7-8-2018

- Ministero Sviluppo Economico € 62,692, I4ALL - Internet for all, D. Nardi, ending 31-12-2018
- MIUR-PRIN 2012 € 55.713, AMANDA: Algorithmics for MAssive and Networked Data, C. Demetrescu, ending 8-3-2017
- MIUR-PRIN 2015 € 84,000, Comparing Governance Regime Changes in Higher Education: systemic performances, national policy dynamics, and institutional responses. A multidisciplinary and mixed methods analysis, C. Daraio, 05-02-2020

Contracts with Companies

- ACI Informatica S.p.A. € 447.980, Sperimentazione e realizzazione prototipale di sistemi tecnologici basati su ontologia per la gestione integrata di banche dati riguardanti i veicoli - Rif. CIG 66898173A1, M. Lenzerini, ending 28-07-2019
- Associazione Nazionale Comuni Italiani - ANCI € 20,000, Gestione, organizzazione e realizzazione, da parte del Dipartimento, del corso di formazione sul tema "La mobilità e la gestione del trasporto pubblico locale", T. D'Alfonso, ending 31-12-2017
- Clementoni S.p.A. € 17,250, Esecuzione di un programma di ricerca concernente l'analisi dell'attività didattica legata all'insegnamento del coding nella scuola materna e in quella primaria, L. Iocchi, 23-11-2017
- Clementoni S.p.A. € 3,000, Addendum n. 01 al contratto di ricerca di cui al Repertorio n. 02/2017 per attività di Divulgazione scientifica. Disseminazione dei risultati di ricerca del progetto in conferenze scientifiche sulla robotica educativa e nell'ambito di iniziative di robotica educativa, inclusa RoboCupJunior, L. Iocchi, ending 03-11-2017
- Comando Generale del Corpo delle Capitanerie di Porto € 30,000, Analisi dell'attuale sistema di Controllo di Gestione del Corpo delle Capitanerie di Porto; Individuazione degli indici di efficienza di riferimento; Studio di Ingegnerizzazione della rilevazione dei parametri di efficienza riferiti ad aree omogenee, A. Nastasi e F. Nonino, ending 03-07-2017
- Paybay Networks S.r.l. € 49,000, Valutazione dell'adeguatezza dell'infrastruttura tecnologica esistente, in particolare per quanto riguarda l'erogazione del servizio di Buono Pasto Elettronico: identificazione delle necessità di sviluppo tecnologico rispetto alle necessità del business del gruppo; analisi di eventuali scelte di rivisitazione e/o riorganizzazione della piattaforma tecnologica proposte dalla funzione Architetture della Parte Committente, B. Ciciani, ending 26-08-2017
- Thales Alenia Space Italia SpA € 51,983, Esecuzione attività di ricerca nell'ambito di una collaborazione sul tema: "Studio di nuove tecnologie per Sistemi Satellitari di Navigazione e Telecomunicazione", F. Delli Priscoli, ending 12-03-2018

- Thales Alenia Space Italia SpA € 21,878, Studio di nuove tecnologie per Sistemi Satellitari di Navigazione e Telecomunicazione, F. Delli Priscoli, ending 30-04-2018
- Thales Alenia Space Italia SpA € 29,255, Esecuzione attività di ricerca nell'ambito dei seguenti temi: 1) "Analisi e modelli in ambito ingegneria sistema satellite"; 2) "Modelli ed uso della propulsione elettrica in ambito spaziale", F. Delli Priscoli, ending 30-04-2018
- Università della Svizzera Italiana € 78.200, ETER2 - SERVICE CONTRACT EAC - 2015-280 - Implement and disseminate the European Tertiary Education Register (ETER 2015-2017), C. Daraio, ending 31-7-2017

Research Agreements (Convenzioni)

- Aero Sekur S.p.A., ending 18-04-2017
- Azienda Ospedaliera - Complesso Ospedaliero S.Giovanni Addolorata, ending 24-3-2018
- Braintrends S.r.l., ending 28-07-2020
- CESVITER - Centro Internazionale di Studi per l'Innovazione e lo Sviluppo Territoriale, ending 2-2-2019
- CINI Consorzio Interuniversitario Nazionale per l'Informatica, ending 30-05-2020
- Club Dirigenti Tecnologie Dell'Informazine di Roma - CDTI, ending 02-04-2017
- CRAT (Finanziamento di due assegni di ricerca), ending 12-12-2018
- CREA, ending 23-01-2020
- DIS Dipartimento per la Sicurezza, ending 04-10-2018
- ENAC (Finanziamento di un assegno di ricerca), ending 27-11-2019
- Eugeni Tecnologie S.r.l., ending 31-12-2017
- Fondazione S. Lucia (Borsa dottorato), ending 30-09-2017
- Fondazione S.Lucia (Collaborazione scientifica), ending 13-10-2019
- IASI-CNR, ending 28-07-2020
- INEMA S.r.l., ending 23-3-2018
- INTERSAJ S.r.l., ending 17-02-2017
- Ministero delle Infrastrutture e dei Trasporti, ending 26-07-2019
- NCFU (Sostegno finanziario di un dottorando), ending 31-10-2019

- NTT Data Italia S.p.A., ending 15-12-2017
- Project Management Institute - PMI, Rome Italy Chapter, ending 22-6-2018
- Società UP S.r.l., ending 29-05-2017
- STIE S.p.A., ending 05-04-2017

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**
- **Economics**
- **Engineering in Computer Science**
- **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
- Methods and Techniques for Neuroengineering
- Bioengineering for Molecular Biology and Bioinformatics
- Processing and analysis of bioelectrical signals

Members: Laura Astolfi, Febo Cincotti (leader), Lorenzo Farina, Serenella Salinari (leader ad honorem, retired).

PhD Students: Yuri Antonacci, Alessandra Anzolin, Stefano Caschera, Emma Colamarino, Marianna Inglese, Maria Grazia Puxeddu, Mirko Rossi.

Post Docs: Angela Ciaramidaro, Manuela Petti, Jlenia Toppi.

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 and biological systems. Researches on biomedical applications have been performed since the early 70's with regard to biomechanics, prostheses and modelling of cellular growth. 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, and by designing innovative instrumentation for neurorehabilitation.

The main research topics are:

- Modelling and Identification of tumor response to radiations;
- Analysis and modeling of insulin secretion and glucose metabolism;
- Estimation of cerebral connectivity in humans by means of structural and functional models and applications;
- Design and validation of EEG-based Brain-Computer Interfaces for assistive and rehabilitation purposes;
- Computational modeling and analysis of omics data.

Research goals include: the study of the mechanisms on the basis of insulin secretion and on the insulin resistance; the potential application of the Brain Computer Interface (BCI) techniques in the rehabilitation of stroke patients; the utilization of the neuroengineering tools in the field of the economy/marketing; the 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.

Among other international recognitions, in 2015 Laura Astolfi has been elected Chair of the Technical Committee di IEEE EMBS in Biomedical Signal Processing.

Several 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 Roma; IRCCS Fondazione Santa Lucia (Roma); Istituto di Medicina Interna Università Cattolica - Policlinico A. Gemelli (Roma); Laboratorio di Oncogenesi Molecolare, Istituto Nazionale Tumori Regina Elena (Roma); Istituto di Analisi dei Sistemi e Informatica (IASI) – CNR (Roma); Istituto per le applicazioni del calcolo (IAC) – CNR (Roma); Laboratorio di Genetica Agraria, Dipartimento di Biotecnologie, Università di Verona; Institut del la Santé et de la Recherche Medicale-Unité 870 Faculté de Medicine Lyon; Conway Institute of Biomolecular and Biomedical Research University College, Dublin; Bariatric and Metabolic Surgery, King's College, London; 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; Dpt. of Biomedical and Electrical Engineering - University of South California (USA); ECE Kansas State University (USA); New Zealand Brain Research Institute, Christchurch, New Zealand.

Projects:

- *Brain-to-brain connectivity from simultaneous neuroelectric and autonomic multi-subjects recordings as a new tool to study human social interaction.* Progetto MIUR Futuro in Ricerca 2013 (Responsabile L. Astolfi).
- *Multimodal classification of upper limb movements during post-stroke rehabilitation.* Progetto di Ateneo - Avvio alla ricerca 2017 (Responsabile E. Colamarino).
- *APOSTROPHES - Assisting Post Stroke Rehabilitation through real time Physiological Signal analysis.* Progetto di Ateneo 2015 (Responsabile F. Cincotti).
- *MIME-BCI - Mindfulness mediatation.* Progetto di Ateneo 2016 - Interdisciplinare (Responsabile F. Cincotti).
- *EMBRACING: Estimating Multiple-BRain connectivity in Autism during Cooperative Interaction: a new tool for real-time hyperscanning.* Progetto di Ateneo 2017 (Responsabile L. Astolfi).
- *Convenzione stipulata tra il Dipartimento e l'IRCCS Fondazione Santa Lucia per il cofinanziamento (66%) di una borsa triennale per il Corso di Dottorato di Automatica, Bioingegneria e Ricerca Operativa, XXX ciclo.*
- *MoRe-Net - MOfor REcovery supported by hybrid Brain-Computer Interface and complex NETWORK theory* Progetti di ricerca congiunti per la mobilità di studenti di dottorato di ricerca. (E. Colamarino, M.G. Puxeddu)

3.2 Economics

3.2.1 Innovation, Internationalization and the Environment

Research lines:

- R&D and Innovation
- Internationalization and the Environment
- Migration and Innovation
- Renewable Energy Sources and Environmental Policies

Members: Francesca Sanna-Randaccio (leader), Roberta Sestini.

Post Docs: Chiara Conti.

This group has recently investigated the theoretical explanations and empirical implications of some interrelated phenomena, namely, technological innovation - with a particular emphasis on R&D agreements -, strategic behavior of Multinational Enterprises (MNEs) in R&D intensive industries, environmental and foreign direct investment (FDI) policies, coalition formation in oligopolies and collusive agreements between firms in the presence of nonprofit organizations. These topics combine two strands of research previously followed by some members of the group. A first line of analysis concerned the study of R&D investment decisions, applying optimal control and dynamic game methods. The other line of enquiry dealt with different aspects of firms' international strategy choices following a game-theoretic approach.

These streams of research have converged, producing in the more recent years a series of results concerning firms' innovative performance, the effects of climate policies on firms' decision to relocate production abroad, the dynamic behaviour of firms' R&D agreements and the role of nonprofit organizations in oligopolistic markets.

Currently the following research topics are under investigation by the group's members:

Endogenous R&D Agreements over Time We introduced a new class of models of endogenous agreements between firms under imperfect competition in which also the timing of actions is made endogenous. The purpose was to bridge two usually separate streams of literature, the noncooperative formation of alliances (R&D agreements, mergers etc.) and the endogenous timing literature. This allowed to consider the formation of firms' agreements over time. The models are currently also employed to study the endogenous formation of environmental agreements among different countries.

Internationalization, Competitiveness and the Environment In pursuing this line of research we deal with the effects of unilateral environmental policies on firms' decision to relocate production abroad and on their technology transfer activities. In other terms,

this research stream addresses the phenomenon of the so-called "carbon leakage", which is a key policy issue both in the EU and the US. We have analyzed this issue first considering a monopoly market structure and then an international oligopoly. More recently the hypothesis of firms' heterogeneity due to different emissions technologies has been incorporated into a model.

Innovation and Diffusion of Clean Technologies This stream of empirical research is motivated by the increased concern that the fragmentation of EU renewable energy research and innovation systems may hamper the ability to address climate challenges at socially acceptable costs. We build a knowledge diffusion econometric model to investigate the intensity and direction of knowledge spillovers in the strategic field of renewable energy technologies. In particular we examine the pattern and evolution of knowledge flows within the EU and between the EU and two frontier innovators: the United States and Japan. We discuss our results trying to assess whether demand-pull environmental measures, introduced with the 1997 Commission White Paper and following Directives, had an impact on the fragmentation of EU research and innovation space.

R&D spillovers, Asymmetric Information and the Incentive to Cooperate in Research Activities Firms' and informational asymmetries have been scarcely taken into account in oligopoly models of strategic R&D. We contribute to fill this gap by investigating the effect of asymmetric information on firms' investment choices and the role of R&D cooperation agreements in a context where asymmetric information regards firms' R&D productivity. Moreover, differently from the past literature, we go further a simple comparison between *regimes*, by assuming that the formation of R&D agreement is endogenous and analyzing the incentive to engage in R&D cooperation. This research highlights a worsening of the under-investment problem due to the presence of asymmetric information, when firms compete in R&D. However, in this context a signaling role of cooperation agreements emerges, leading to higher profit for efficient firms and welfare improvement in some regions of parameters' values. This work also contributes to explain some empirical evidence about the formation and the features of R&D cooperation agreements (RJVs).

Externalities from Migration and Innovation We empirically investigate the effect of immigration on innovation, using patent data and firms' self-reported innovation (product, process and organizational) as outcome variable. The past literature is mainly focused on the positive effects of highly educated immigrants (due to positive self-selection and complementarities with the natives' skills) in countries where high-skilled immigration is a sizeable phenomenon. We instead focus our analysis on Italy, a country characterized by large inflows of low-skilled immigrants and inability to attract high-skilled workers and researchers. We analyze the impact of overall and low-skilled immigration on radical innovation (measured by patents at province level) and also on less formal measures of innovation (using survey firm-level data), particularly relevant in a country like Italy where the level of formal R&D is very low. Our estimation results do not show

any significant negative effect on innovation, that could be a consequence of the inflow of cheap labor force in a country specialized in traditional, low value-added production. These results could be partially explained by the natives' skilled structure, not very different from that of immigrants. Hence, in this context low-skilled immigration does not represent a real shock in labor supply. This research, although focused on a single country, can be informative also for other countries with a similar economic structure, which are likely to be affected by large immigration in the near future.

3.3 Engineering in Computer Science

3.3.1 Algorithm Design and Engineering

Research lines:

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

Members: Aris Anagnostopoulos, Giorgio Ausiello (leader ad honorem, emeritus), Fabrizio D'Amore, Camil Demetrescu (leader), Stefano Leonardi, Alberto Marchetti-Spaccamela, Umberto Nanni.

Post Docs: Andrea Ribichini, Emilio Coppa, Daniele Cono D'Elia.

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 algorithms and data structures for graph problems;
- Performance Engineering: design and implementation of methodologies and tools for analyzing 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 network 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 algorithmic 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 focus on problems arising from the scheduling of recurrent tasks in real-time systems. 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 consider the simultaneous approximation on several objective functions and on network 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 representations, based on graphs and hypergraphs, suitable to model processes and biological systems. Then, working with groups of researchers in other disciplines - such as bioinformatics and elearning - we aim at boosting research results in these areas.

Projects:

- *AMANDA: Algorithmics for MAssive and Networked DAta* - February 2013, February 2017 - PRIN MIUR

3.3.2 Algorithms and Data Science

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.

Research lines:

- Web Search and Mining
- Graph and Text mining
- Large-scale Complex Networks
- On-line Social Networks
- Algorithmic Mechanism Design and Network Economics

Members: Aris Anagnostopoulos, Luca Becchetti, Stefano Leonardi (leader).

PhD Students: Reem Atassi (graduated in 7/2017), Michel Gentili, Cristina Menghini, Stefano Piersanti, Mara Sorella (graduated in 7/2017).

Post Docs: Adriano Fazzino, Chris Schwiegelshohn

Projects:

- *Web Algorithmics for Large-Scale Data Analysis*, Google Focused Research Award, 2014–current.

3.3.3 Artificial Intelligence and Knowledge Representation

Research lines:

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

Members: Luigia Carlucci Aiello, Giuseppe De Giacomo (leader), Domenico Lembo, Maurizio Lenzerini, Paolo Liberatore, Daniele Nardi, Fabio Patrizi, Antonella Poggi, Riccardo Rosati.

PhD Students: Federico Croce, Federico Maria Scafoglieri, Marina Morelli, Gianluca Cima.

Post Docs: Lorenzo Lepore, Marco Ruzzi, Valerio Santarelli, Domenico Fabio Savo.

Other Collaborators: Giacomo Ronconi.

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, LTL_f , and LDL_f ; 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.

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

Awards and honours include: AAAI Fellowships: Maurizio Lenzerini, since 2017; Giuseppe De Giacomo, since 2016; Luigia Carlucci Aiello, since 1995; EurAI Fellowships: Riccardo Rosati, since 2016, Giuseppe De Giacomo, since 2012, Daniele Nardi, since 2009, Maurizio Lenzerini, since 2008; Luigia Carlucci Aiello, since 1999; Membership to the *European Academy of Sciences and Arts* (Luigia Carlucci Aiello, since 2005); ACM Fellowships (Maurizio Lenzerini, since 2009; Giuseppe De Giacomo, since 2016); Membership to the *Academia Europaea –The Academy of Europe* (Maurizio Lenzerini, since 2011); IJCAI *Distinguished Service Award* (Luigia Carlucci Aiello, 2009); ECCAI *Distinguished Services Award* (Luigia Carlucci Aiello, 2014); Doctorate Honoris Causa (Luigia Carlucci Aiello, 2002, School of Technology, University of Linköping, Sweden); ACM *Recognition Service Award* (Maurizio Lenzerini, 2011).

Several group members are involved in various prestigious editorial activities: Giuseppe De Giacomo is Review Editor of *Artificial Intelligence* (Elsevier) and member of the Editorial Board of *Acta Informatica*, he is Vice-President of the Steering Committee Member of the *International Conference on Principles of Knowledge Representation and Reasoning* (KR), he is Area Chair of the *27th International Joint Conference on Artificial Intelligence* (IJCAI 2018) and of the *32nd AAAI Conference on Artificial Intelligence* (AAAI 2018); Domenico Lembo is Steering Committee Member of the *International Conference on Web*

Reasoning in Rule Systems (RR), since 2016, and Chair of the 13th *Reasoning Web Summer School (RW 2017)*. Maurizio Lenzerini is Area Editor of *Information Systems –An International Journal*, for the area of Data Modeling and Knowledge Representation and Reasoning Techniques, Editorial Board member of *Intelligenza Artificiale*, The International Journal of the *AI*IA*, Area Editor of the *Journal of Applied Logic* for the area of Logic for Knowledge Representation and the Semantic Web, Editorial Board member of the *Logical Methods in Computer Science (LMCS) Journal*, for the areas of Database Theory and Logic for Knowledge Representation, and Area Editor of the *Logic Journal of the Interest Group in Pure and Applied Logic (IGPL)*, for the area of Logic for Knowledge Representation and the Semantic Web, he has been co-Chair of the 29th *International Workshop on Description Logics (DL 2016)*, since 2011 he is Member of the *ACM SIGMOD Awards Committee*, since 2006 he is Member of the Executive Committee of the *ACM Principles of Database Systems (PODS)*, and since 2005 he is Member of the *Sistemi Evoluti di Basi di Dati (SEBD) Steering Committee*, he is also Member of the Scientific Advisory Board of *BiCi –Bertinoro international Center for Informatics* and Member of the Advisory Board of the *European Research Institute in Service Science (ERISS)*.

Riccardo Rosati is Member of the Editorial Board of *Artificial Intelligence (Elsevier)*, Steering Committee Member of the *International Workshop on Nonmonotonic Reasoning (NMR)*, since 2012.

Finally, the following invited talks were delivered:

- Giuseppe De Giacomo, *First-Order mu-Calculus over Generic Transition Systems and Applications to the Situation Calculus*, invited talk at the 1st Workshop on Formal Methods in AI, University of Naples "Federico II", Naples, Italy, February 2017;
- Giuseppe De Giacomo, *AI Foundations for Data-Aware Business Processes*, distinguished talk at York University's Centre for Innovation in Computing at Lassonde (IC@L), Toronto, ON, Canada. Also given at University of Toronto, April 2017.
- Giuseppe De Giacomo, *Foundations of Planning for LTLf and LDLf Goals*, invited talk at ICAPS 2017 Workshop on Generalized Planning, Pittsburgh, PA, USA, June 2017.
- Giuseppe De Giacomo, *AI Foundations for Cognitive BPM*, Invited talk at BPM 2017 Workshop on Cognitive Business Process Management (CBPM 2017) Barcelona, Spain, September 2017.
- Domenico Lembo invited Lecturer on Data Integration at the EDBT 2017 summer school, Genoa, Italy, September 2017.
- Domenico Lembo, Valerio Santarelli and Domenico Fabio Savo *Methods and Tools for Developing Ontology-Based Data Access Solutions* tutorial at the 16th International Semantic Web Conference (ISWC 2017), Vienna, Austria, October 2017.

Projects:

- *ICE : Immersive Cognitive Environments*, Award Sapienza research project;, December 2015 - December 2018. Giuseppe De Giacomo.

3.3.4 Artificial Intelligence and Robotics

Research lines:

- Robot World Modeling
- Information Fusion
- Social Robotics and Human-Robot Interaction
- Robot Learning
- Multi-Agent and Multi Robot Systems
- Robotic Competitions and Benchmarking

Members: Giorgio Grisetti, Luca Iocchi, Daniele Nardi (leader), Alberto Pretto.

PhD Students: Taigo Maria Bonanni, Roberto Capobianco, Maurilio Di Cicco, Jacopo Serafin, Francesco Riccio, Marco Imperoli, Ciro Potena, Andrea Vanzo, Ali Youssef, Wang Lun, Paola Ferrarelli, Bartolomeo Della Corte, Dario Albani, Dominik Schlegel, Irvin Aloise, Mirco Colosi.

Post Docs: María Teresa Lázaro.

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 analyzing 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 Rescue, @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 experimentally evaluated, include virtual agents and multi-robot systems in soccer, search and

rescue, 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:

- Prof. Sean Luke, Department of Computer Science, George Mason University (January-June 2017)

The following is a list of relevant activities by the members of the group:

- Luca Iocchi and Daniele Nardi have been members of the Board of Trustees of the RoboCup Federation, 2017.
- The SPQR team of humanoid soccer players and of RoboCup@Work participated in RoboCup German Open 2017, Magdeburg, Germany.
- The SPQReL team (joint team with University of Lincoln, UK) participated in European Robotics League Service Robot 2017 competition, gaining the award for the Speech Recognition Functional Benchmark, and in RoboCup@Home 2017 Nagoya, Japan., achieving the 3rd Place.
- Organization of European Robotics League Service Robot Local Tournament in Pescioli, Italy (January 30-February 3, 2017).

Projects:

- *COACHES* (EU Chist-era). October 2014 - September 2017. Luca Iocchi and Daniele Nardi.
- *Flourish* (EU Horizon2020). March 2015–August 2018. Alberto Pretto, Giorgio Grisetti, and Daniele Nardi.
- *Flexsight* (EU FP7, Experiment in ECHORD++). September 2016 - March 2018. Alberto Pretto, and Daniele Nardi.
- *RockEU2* (Horizon 2020 programme). February 2016–August 2018
- *SCIROC* (Horizon 2020 programme). Agreement signed in 2017, the project will span through February 2018–January 2022.
- *Internet4All* (MISE project). January 2017–December 2018.

3.3.5 Computer Networks and Pervasive Systems

Research lines:

- Wireless and Sensor Networks
- Networks of Resource Constrained Devices
- Streaming Applications over Wireless
- Network Coding
- Self-* Protocols and Systems
- People Centric Sensing
- Internet of Things

Members: Luca Becchetti, Roberto Beraldi, Ioannis Chatzigiannakis, Alberto Marchetti Spaccamela (leader), Leonardo Querzoni, Andrea Vitaletti.

PhD Students: Fabio Angeletti

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 networks of tiny artefacts. One specific topic of interest is the study of advanced adaptive routing algorithms in ad hoc wireless networks that are efficient and reduce the energy requirements at wireless nodes.

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 the future we plan to address security and privacy issues of such networks. In fact the limited available resources requires new techniques and algorithms. We complement our research with 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 analyse the so called proximity graph, namely a graph in which nodes are users and there is a link between two nodes if their are in proximity). We are also interested in experimenting our ideas on smart mobile phones in the context of augmented reality and fully decentralized recommendations.

Projects:

- *Designing Human-Agent Collectives for Sustainable Future Societies* - Progetto di Ricerca Sapienza 2017

3.3.6 Computer Vision, Computer Graphics, and Perception

Research lines:

- Human Motion Analysis, Gesture Recognition, Physics based methods, Activity Understanding from 3D data
- Saliency Prediction, Visual Attention, Activity Recognition
- Dense Image Fusion, Meshing, 3D Surface Reconstruction
- Scene Representation, Interpretation and Understanding
- Component Based Articulated Object Reconstruction
- Terrain Traversability in Rescue Environments
- Patterns for Zooming Camera Calibration
- Learning of Visual Object Categories
- Control for Polyarticulated Self-Powered Hand Prostheses
- Adaptive, Flexible Cognitive Control under Task Switching for Rescue Robots
- 3D Motion Planning for Articulated Unmanned Tracked Vehicles
- Visual Media Analysis, Indexing, Classification and Retrieval
- Management of Digital Resources
- Augmented Reality and Computer Animated Virtualization

Members: Fiora Pirri (leader), Barbara Caputo, Marco Schaerf, Luca Iocchi, Mario Gianni, Valsamis Ntouskos, Luigi Freda.

PhD Students: Angela Di Iorio, Manuel Alejandro Ruiz Garcia, , Marta Sanzari, Francesco Puja, Federico Ferri, Fabio Maria Carlucci, Andrea Gigli, Antonio D'Innocente, Valentina Gregori, Massimiliano Mancini, Nizar Massouh, Paolo Russo.

Collaborators: Simone Grazioso, Elham Omrani Antonio Tammaro.

The problem of Human Action Recognition is investigated, in our research work, within Motion Capture sequences. In this context, 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 compare 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.

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.

In the coherence theory of attention, introduced by Rensink, O'Regan, and Clark (2000), a coherence field is defined by a hierarchy of structures supporting the activities taking place across the different stages of visual attention. At the interface between low level and mid-level attention processing stages are the proto-objects; these are generated in parallel and collect features of the scene at specific location and time. These structures fade away if the region is no further attended by attention. This research work aims to build methods to computationally model these structures, on the basis of data collected in dynamic 3D environments via the Gaze Machine, a gaze measurement framework.

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.

Learning a visual object category from few samples is a compelling and challenging problem. In several real-world applications collecting many annotated data is costly and not always possible. However a small training set does not allow to cover the high intraclass variability typical of visual objects. In this condition, machine learning methods provide very few guarantees. This research activity concentrates on discriminative model adaptation algorithms able to proficiently learn a target object with few examples, relying on other previously learned source categories.

The main means of control for polyarticulated self-powered hand prostheses is surface electromyography (sEMG). In the clinical setting, data collected from two electrodes are used to guide the hand movements selecting among a finite number of postures. Machine learning has been applied in the past to the sEMG signal (not in the clinical setting) with interesting results, which provide more insight on how these data could be used to improve prosthetic functionality. However, developing a finer control requires a longer training period. A desirable characteristic would be to shorten the time needed by a patient to learn how to use the prosthesis. To this aim, our research work focuses on exploiting methods to reuse past experience, in the form of models synthesized from previous subjects, to boost the adaptivity of the prosthesis.

Modeling cognitive control is a major issue in robot control, and it is about deciding when a task cannot succeed and a new task need to be initiated. These decisions are induced by incoming stimuli alerting of events taking place while the robot is executing its duties. The research work on modeling robot adaptive behaviors, under salient stimuli, exploits the human inspired paradigm of shifting and inhibition, underlying task switching.

Tracked vehicles are currently used in search and rescue, military, agricultural and planetary exploration applications where terrain conditions are difficult and unpredictable. They are better suited for such tasks than wheeled vehicles due to the larger contact area of tracks with the ground, which provides better traction on harsh terrains. These environments are often inaccessible or considered too dangerous for humans to operate in, thus requiring the tracked vehicle to be endowed with autonomous navigation, safe locomotion and human-robot interaction capabilities to assist humans in complex tasks such as rescue, scouting or transportation. To cope with this challenging task, our research activities pursue to develop control models to allow articulated tracked vehicles to autonomously follow 3D paths, within cluttered environments, adapting their morphology to the complexity of the terrain.

The research work, concerning the management of digital resources, explores the applicability of the SDL metadata framework to support preservation, management and dissemination of the Sapienza Digital Library (SDL) resources. The applicability study has been proved to be useful to improve the SDL interoperability in the management of the differences in information granularity, and to fulfil the lack or to avoid the waste of information.

Within the context of our research activities, Augmented Reality is becoming a compelling technology mainly for the interactive 3D visualization 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. The latter application constitutes an important research test-bed for robots, meeting the needs to test and experiment complex robot behaviors using such a dynamic and rich perceptual domain.

Projects:

- *RoboExNovo - Robots learning about objects from externalized knowledge sources* - 2015, 2020 - ERC-2014-STG
- *SecondHands - A Robot Assistant for Industrial Maintenance Tasks* - 2015, 2020 - H2020 ICT-2014-1
- *TRADR - Long-Term Human-Robot Teaming for Robot Assisted Disaster Response* - 2014, 2018 - FP7 ICT 609763.
- *ALOOF - Autonomous Learning of the Meaning of Objects* - 2014, 2017 - ERA-Net CHIST-ERA.

3.3.7 Cybersecurity

Research lines:

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

Members: Roberto Beraldi, Roberto Baldoni, Silvia Bonomi, Fabrizio d'Amore, Francesco Delli Priscoli, Camil Demetrescu (leader), Alessandro Di Giorgio, Luca Iocchi, Riccardo Lazzeretti, Domenico Lembo, Alberto Marchetti Spaccamela, Massimo Mecella, Antonio Pietrabissa, Leonardo Querzoni, Riccardo Rosati, Giuseppe Santucci.

PhD Students: Alessandro Giuseppi, Giuseppe Laurenza, Simone Lenti, Luca Massarelli.

Post Docs: Leonardo Aniello, Marco Angelini, Claudio Ciccotelli, Emilio Coppa, Daniele Cono D'Elia, Luca Montanari, Domenico Fabio Savo.

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 for malware analysis — 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 exist that allow users to develop and deploy his/her own blockchain. We are studying issues related to blockchain scalability (in terms of achieved performance) and security against external attacks.

Cyber-physical systems — Protection and preventive control of cyber-physical systems 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.

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 samples 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 INTeelligence (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 problems 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 being 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 pro-

cessing 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 off-putting 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 non-interactive 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 counter-measures. 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.

Projects:

- *ATENA, Advanced Tools to assess and mitigate the criticality of ICT components and their dependencies over Critical Infrastructures* (managed by CRAT) - May 2016, April 2019 - EU MG H2020 Project.
- *PROMETEO, Protezione di reti elettriche di potenza da attacchi ciber-fisici mediante strategie di controllo*, progetto di Ateneo, prot. RM11715C7EFAF857.
- *FILIERASICURA* (managed by CINI) - December 2016, December 2019 - Industrial project with CISCO and Leonardo.
- *SUNFISH* - January 2015, December 2017 - EU H2020.
- *EURASIA* - October 2016, October 2018 - Italy-Israel joint project.

3.3.8 Data Management and Service-Oriented Computing

Research lines:

- Data Integration and Exchange
- Ontology Based Data Management
- Data Warehousing, Data Quality and Data Cleaning
- Process and Workflow Management
- Service Modeling
- Service Synthesis and Composition

Members: Tiziana Catarci, Giuseppe De Giacomo, Domenico Lembo, Maurizio Lenzerini (leader), Massimo Mecella, Fabio Patrizi, Antonella Poggi, Riccardo Rosati, Silvio Salza.

PhD Students: Gianluca Cima, Federico Croce, Federico Scafoglieri, Daniele Sora.

Post Docs: Francesco Leotta, Lorenzo Lepore, Andrea Marrella, Marco Ruzzi, Valerio Santarelli, Domenico Fabio Savo.

Our interest in Data Management dates back to the '80s, 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 applications. We are particularly interested in service modeling and automatic service composition. In this area, we proposed what in the community is now known as the "Roman model", and contributing to one of the first solutions to automated service composition.

Since its introduction, the Roman model has been studied by several research groups worldwide, and is one of the key references in the formal approaches to automated service composition. We have also studied Service Synthesis, as well as Process and Workflow Management, with a special focus on principles and techniques for modeling the interaction between processes and data.

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

- (i) posing the semantics of the application domain at the center of the scene,
- (ii) combining the management of data with the management of the processes and services using such data in the organization, and
- (iii) shifting the role of the conceptual model from a design-time to a run-time artifact.

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

In 2017, members of the research group have been invited to organize various events, and to deliver keynote speeches at various conferences and workshops: Tiziana Catarci is Editor-in-Chief of the ACM Journal of Data and Information Quality (JDIQ), Editor-in-Chief of the journal EAI Endorsed Transactions on Ambient Systems, Editorial Board member of the World Wide Web Journal (WWWJ), Editorial Board member of the Journal on Data Semantics, member of the Big Data Committee of the Italian National Institute of Statistics (ISTAT), and member of the *European Academy of Sciences and Arts*; Domenico Lembo is Steering Committee Member of the *International Conference on Web Reasoning and Rule Systems* (RR 2017); Maurizio Lenzerini is Chair of the AI*IA Somalvico Award (Premio Somalvico) Committee 2017, member of the ACM SIGMOD Awards Committee 2017, member of the 2017 "Lombardia è ricerca" Prize Committee - a new annual scientific prize of one million Euros to be assigned for outstanding research in life and data science, Area Editor of *Information Systems* - an International Journal for the area of Data Modeling and Knowledge Representation and Reasoning Techniques, Area Editor of *Logic Journal of the IGPL* (Oxford Journal of the Interest Group in Pure and Applied Logic), for the area of Logic for Knowledge Representation and the Semantic Web, Area Editor of *Journal of Applied Logic* for the area of Logic for Knowledge Representation and the Semantic Web, Editorial Board member of the LMCS - Logical Methods in Computer Science, for the areas of Database theory and Logic for knowledge representation,

Editorial Board member of *Big Data Research* (Elsevier), Editorial Board member of *Intelligenza Artificiale* - the International Journal of the AI*IA. Andrea Marrella is Information Director and Admin of the ACM International Journal on Data and Information Quality (JDIQ), and Associate Editor (Editorial Board Member) of the International Journal of Information Systems for Crisis Response and Management (IJISCRAM). He was also Keynote Speaker at the 1st International Workshop on BP Innovation with AI (BPAI'17) and Tutorial organizer at the 18th Int. Conf. on Product-Focused Software Process Improvement (PROFES 2017), where he also delivered the tutorial "Process Mining: from Zero to Hero". Massimo Mecella is co-Chair of practi-o-web 2017, International Workshop on The Practice of the Open Web, co-Chair of BP-Meet-IoT 2017, the 1st International Workshop on Business Processes Meet IoT. Domenico Fabio Savo was Keynote Speaker at the 1st International Workshop on the Practice of Open Web (practi-o-web 2017). Antonella Poggi, delivered an invited talk at the conference "La descrizione archivistica e gli archivi nel web. L'evoluzione degli standard, le tradizioni nazionali". Finally, Domenico Lembo, Valerio Santarelli and Domenico Fabio Savo have delivered a *Tutorial on Methods and Tools for Developing Ontology-Based Data Access Solutions*, held at the 16th International Semantic Web Conference (ISWC 2017).

Projects:

- VOICE - Virtual Open Incubation Ecosystem, September 2014 - August 2017 (EU FP7).
- MAGISTER - Multidimensional Archival Geographical Intelligent System for Territorial Enhancement and Representation, December 2015 - November 2017. Research project funded by Regione Lazio.
- PRE-O-PRE - PREserving Open data while opening PREserved data, November 2016, October 2017. Research project funded by Sapienza.
- MODEUS - Making Open Data Effectively USable, September 2015 - September 2018. SIR research project funded by MIUR, grant n. RBSI14TQHQ.
- “Integrazione dei dati basata su ontologie nel dominio della fiscalità dell’auto”, February 2016 - February 2019. Project funded by ACI INFORMATICA S.p.A.
- “Design and Maintenance of Ontology-Based Data Access Systems”, January 2017 - December 2017. Research project funded by Sapienza.
- “Ontology-based open data publishing”, January 2017 - December 2017. Research project funded by Sapienza.

3.3.9 Distributed Systems

Research lines:

- Secure and robust distributed systems
- Event-based Systems
- Stream processing systems
- Resource Sharing Systems
- Smart Environments
- Distributed Systems Interoperability

Members: Roberto Beraldi, Roberto Baldoni (leader), Silvia Bonomi, Bruno Ciciani, Francesco Quaglia, Leonardo Querzoni.

PhD Students: Federico Lombardi, Daniele Ucci.

Post Docs: Leonardo Aniello, Emanuele Borzi, Claudio Ciccotelli, Antonella Del Pozzo, Luca Montanari.

The Distributed Systems group has developed, in the last ten 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. In the last ten years the group has developed several theories and practical experiences in several topics including checkpointing, causal and total ordering theory, distributed replication systems, interceptors, group toolkits, and publish subscribe systems.

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 the financial infrastructure. 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. Our activities are centered around the MidLab laboratory and the Research Center of Cyber Intelligence and Information Security (CIS).

MidLab is focussed on research; its primary goal is to support leading-edge research and development on middleware bridging the gap between the latest research results and the current technologies. In particular main MIDLAB targets are the study, the design and analysis of novel middleware platforms able to increase the robustness of information exchanging with respect to reliability, consistency, predictability and security. In the last few years MidLab members have also started to pursue new research trends in the area of high-performance stream processing systems and graph-based computations.

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.

Projects:

- *FILIERASICURA* - December 2016, December 2019 - Industrial project with CISCO and Leonardo.
- *SUNFISH* - January 2015, December 2017 - EU H2020.
- *PANOPTESSEC* - November 2013, October 2016 - EU IP FP7.
- *EURASIA* - October 2016, October 2018 - Italy-Israel joint project.
- *ROMA - Resilience Enhancement of Metropolitan Areas* - November 2013, November 2017 - MIUR Smart Cities.
- *CIS-SOGEI Collaboration* - June 2015, May 2016 - Industrial project.
- *T-NOVA - Network Functions as-a-Service over Virtualised Infrastructures* - January 2014, December 2016 - EU Strep FP7.
- *TENACE, Protecting National Critical Infrastructures from Cyber Threats* - February 2013, January 2016 - PRIN MIUR.

3.3.10 High Performance and Dependable Computing Systems**Research lines:**

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

Members: Bruno Ciciani (leader), Francesco Quaglia.

Post Docs: Pierangelo Di Sanzo, Alessandro Pellegrini.

PhD Students: Davide Cingolani, Simone Economo, Mauro Ianni, Romolo Marotta, Stefano Conoci, Emiliano Silvestri.

The High Performance and Dependable Computing Systems research group is 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:

- 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 platforms, 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 plan to target innovative programming models and paradigms, such as sequential/concurrent programming based (a) on 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.

Projects:

- *SATURN: Spatio-Temporal Cloud Store for Big-Data Applications* - 2015–2018.

3.3.11 Human-Computer Interaction

Research lines:

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

Members: Tiziana Catarci (leader), Massimo Mecella, Giuseppe Santucci, Marco Temperini.

PhD Students: Francesco Sapio, Mahmoud Sharf, Daniele Sora, Annalisa Terracina

Post Docs: Marco Angelini, Andrea Marrella, Francesco Leotta

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 information 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 international 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 information 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.

Scientific roles:

- Tiziana Catarci is Editor in Chief of EAI Transactions on Ambient Systems.
- Giuseppe Santucci is in the Steering Committee of IEEE Conference on Visual Analytics Science and Technology - VAST
- Giuseppe Santucci is in the Steering Committee of EG/VGTC Conference on Visualization - EUROVIS

Projects:

- *NEPTIS* - January 2015 – March 2018 - Italian PON (PON03PE_00214)
- *ITSHIRT* - 2018 – 2020 – Sapienza project

3.4 Management Engineering

3.4.1 Industrial Organization and Management

Research lines:

- Competition, Regulation and Industrial Policy
- Mechanism Design and Auctions
- Economics and Management of Education and Research
- Efficiency and Productivity Analysis
- Management Control Systems
- Operations Management
- Industry Studies: Media, Telecommunications, Transportation, Utilities, and Services

Members: Alessandro Avenali, Giuseppe Catalano, Tiziana D'Alfonso, Rosa Maria Dangelico, Cinzia Daraio, Domenico Laise, Claudio Leporelli (leader), Giorgio Matteucci, Alberto Nastasi, Fabio Nonino, Pierfrancesco Reverberi.

PhD Students: Francesco Bombasaro, Cosimo Dolente, Martina Gregori, Giulia Palombi, Alessandro Pompei, Luigi Scuncio.

Post Docs: Graziella Bonanno.

The research activity of the group, that includes general issues in industrial economics, public policy and management, is performed by three research groups: *Industrial Organization, Management and Efficiency, Effectiveness and Impact Analysis of Education and Research: methods and applications.*

The *Industrial Organization* research group focuses on the following topics:

- *Competition, regulation, incentives to investments and industrial policy in network industries* (with a focus on telecommunications, air transport, rail transport, local public transport and utilities), in the media industry and in the pharmaceutical sector. For this purpose, the group develops and makes use of game theory, cost proxy models, econometrics, and economic models for the evaluation of investments.
- *Productivity and efficiency analysis*, with a focus on the development of parametric and non-parametric methods which can be applied to different fields in Economics and Management.
- *Economics and management of education and research activities*, with a focus on the evaluation of performance, accreditation and funding of education institutions located in the main European countries. For this purpose, the group develops and makes use of efficiency analysis and econometrics.

- *Mechanism design*, with a focus on the analysis and the development of auction procedures for the efficient allocation of scarce resources, characterized by complementarities or substitutability effects, and on the innovation of procurement systems. For this purpose, the group develops and makes use of agent-based simulation models, game theory and mathematical programming.

The *Management* research group focuses on the following topics:

- *Management control systems*, with a focus on the analysis of organizational procedures and the development of a system of indicators. For this purpose, the group develops and makes use of the multi-criteria methodology applied to managerial decision making problems.
- *Operations management*, with a focus on the performance analysis of innovative product/services development models, production system and supply-chains in complex organizations.
- *Green Management and Corporate Sustainability*, with a focus on the integration of environmental sustainability into corporate strategies and the analysis of the success factors of the green product development process.

The group *Efficiency, Effectiveness and Impact Analysis of Education and Research: methods and applications* performs both theoretical and empirical analysis aimed to the formulation of recommendations for public policies. In particular, this research group has focused on the following topics:

- *Efficiency, effectiveness of scientific research and educational system*, with particular reference to: the evaluation of higher education, scientific research, technological innovation and their financing; the development of new bibliometric approaches and indicators to assess the scientific competitiveness at country, regional and local level; the analysis of the market structure of higher education in Italy and in the European countries; the analysis of public funding to the university system in Italy and other major European countries; the development of public policies in education and scientific research;
- *Evaluation of the administrative activities of the university*, with particular reference to: e-procurement policies and services to support students, funding systems for students and interventions for student aid (loans and bonus); effectiveness of scholarships; managerial tools for the management of universities and public research institutions; management control systems and strategic planning of universities; management of students' accommodations.

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), has implemented and implements different collaborations with the National Agency for University and Scientific Research Evaluation

(ANVUR), the Ministry of Education, Universities, and Research (MIUR), the Ministry of infrastructures and Transport and the European Commission on the themes of the evaluation of the impact of public policies for higher education and scientific research and on the themes of the standard cost of local public transport.

Projects:

- 2012-2017: Elsevier Bibliometric Research Project: Assessing the Scientific Performance of Regions and Countries at Disciplinary level by means of Robust Non-parametric Methods: new indicators to measure regional and national Scientific Competitiveness;
- 2015-2018: H2020: BONVOYAGE - Intermodal mobility solutions, interfaces and applications for people and goods, supported by an innovative communication network;
- 2015-2017: Implement and Disseminate the European Tertiary Education Register (ETER 2015-2017), European Commission, Contract No. EAC-2015-0280;
- 2015-2017: Sapienza Research Awards no. (C26H15XNFS) Establishing a Knowledge Infrastructure for the Development of Methodologies for the Assessment of Research and its Impacts;
- 2015-2017: Sapienza Research Awards no. (RP11715C76E5E75E) Methods and procedures for the allocation of national public resources in the Italian local public transport sector;
- 2017-2018: Sapienza Research Awards no. (C26N15TJLN) Methods and procedures for the determination of standard costs in the local public bus transport sector;
- 2015-2017: Sapienza Research Awards no. (C26A15ZBPM) Co-investment in ultra-fast broadband access networks: is there a role for content providers?.
- 2015-2017: Sapienza Research Awards no. (C26N1483ET) Intermodality between air transport and high speed rail: social welfare, environmental externalities and regulation.
- 2017-2019: Sapienza Research Awards, Green innovation in family firms: drivers, characteristics, and success factors.

3.5 Operations Research

3.5.1 Combinatorial Optimization

Research Lines:

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

Members: Renato Bruni, Antonio Sassano (leader).

Combinatorial Optimization searches for an optimal set of objects into a finite (but large) collection of sets. Graph Theory, Integer Programming and Polyhedral Combinatorics are the key methodological tools in this area.

The activity of the Combinatorial Optimization Group at DIS 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.

The group is currently cooperating with the University of Maastricht, University of Oslo, Università di Roma Tor Vergata, Università dell'Aquila, Università di Lecce, Politecnico di Milano, Università del Sannio, Istituto Nazionale di Statistica (Istat), Texas Tech University, ZIB Berlin. The group has been involved in a large number of national and international projects. In the last 10 years the group 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. Recently the group received a prestigious international award from the Association of European Operational Research Societies (EPA 2009). 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 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.

Projects:

- Tecniche di Ottimizzazione Combinatoria per la risoluzione di problemi di Data Mining in campo Economico-Gestionale, progetto di ricerca Sapienza, Dec. 2016 - May 2018.
- Tecniche di Data Mining efficienti, robuste e basate sull'ottimizzazione per la risoluzione di problemi di Classificazione e Selezione di Investimenti, progetto di ricerca Sapienza, Dec. 2014 - May 2016.
- APICE - Algoritmi per la Pianificazione Integrata e Controllo di reti wireless Eterogenee, progetto MIUR n. 2878

3.5.2 Continuous Optimization

Research lines:

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

Members: Alberto De Santis, Marianna De Santis, Gianni Di Pillo (leader ad honorem, emeritus), Francisco Facchinei, Luigi Grippo (retired), Stefano Lucidi (leader), Laura Palagi, Massimo Roma.

PhD Students: Caliciotti Andrea, Tommaso Colombo, Danny D'Agostino, Tommaso Giovannelli, Giorgio Grani, Ludovica Maccarrone, Francesco Romito, Ruggiero Seccia, Marco Viola.

Post Docs: Simone Sagratella.

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, that 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 modelling 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.

3.6 Systems and Control Engineering

3.6.1 Networked Systems

Research lines:

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

Members: Francesco Delli Priscoli (co-leader) and Antonio Pietrabissa (co-leader), Alessandro Di Giorgio, Alberto Isidori (emeritus).

PhD Students: Federico Cimorelli, Raffaele Gambuti, Alessandro Giuseppi, Federico Lisi, Lorenzo Ricciardi Celsi, Andrea Tortorelli.

Post Docs: Silvia Canale, Andrea Fiaschetti, Francesco Liberati, Martina Panfili, Vincenzo Suraci, Letterio Zuccaro.

The networked systems area has developed, in the last 17 years, thanks to the successful participation in 37 major advanced research projects mainly financed by the European Union (EU), carried on together with major European ICT players. The networked systems area supports a Future Internet vision (in particular, the group participated to the large FI-WARE EU project just 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, data mining, game theory, bounded optimal control, 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 in metadata and aggregated in a context-aware fashion), take 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, 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 the 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.

Projects:

- *ATENA, Advanced Tools to assess and mitigate the criticality of ICT components and their dependencies over Critical Infrastructures* (managed by CRAT) - May 2016, April 2019 - EU MG H2020 Project.
- *Bonvoyage, From Bilbao to Oslo, intermodal mobility solutions and interfaces for people and goods, supported by an innovative communication network* (managed by CRAT) - May 2015, April 2018 - EU DS H2020 Project.
- *PROMETEO, Protezione di reti elettriche di potenza da attacchi cyber-fisici mediante strategie di controllo*, progetto di Ateneo, prot. RM11715C7EFAF857.

3.6.2 Nonlinear Systems and Control

Research lines:

- Robust Control
- Stability and Stabilization
- Tracking and Regulation
- Optimal Control and Stochastic Systems
- Hybrid Systems
- Discrete-time and Sampled Data Systems
- Data Acquisition and Sensor Networks
- Control Applications

Members: Stefano Battilotti, Luca Benvenuti, Claudia Califano, Paolo Di Giamberardino, Daniela Iacoviello, Alberto Isidori (leader ad honorem, emeritus), Salvatore Monaco (leader).

PhD Students: Hassan Ahmed Marwa, D'Angelo Massimiliano, Mattia Mattioni, Ricciardi Celsi Lorenzo.

Research on nonlinear systems and control at the University Sapienza has been active since the early 70s and, historically, has played a major role worldwide. The geometric approach to nonlinear feedback design, developed in the late 70s, marked the beginning of a new area of research which, in the subsequent decades, has profoundly influenced the development of the entire field. The concept of (nonlinear) feedback equivalence and of zero dynamics, their properties and implications in feedback design, are perhaps the most frequently used concepts in feedback stabilization. The geometric approach also plays a fundamental role in the analysis of systems evolving on Lie groups, with numerous applications to the control of spacecrafts and mobile robots. The natural evolution of the geometric approach to analysis and design of nonlinear systems led to a refinement of concepts underlying the design of nonlinear controllers to the purpose of shaping the steady-state behavior of a system. Currently, this line of research is pursued with the study of problems arising in the regulation of systems possessing unstable zero dynamics and in the development of methods for robust stabilization via measurement feedback. A general framework for robust stabilization reposes of the concept of filtered Lyapunov functions. Tools for the design of composite filtered Lyapunov functions have been developed. Robust and nonlinear control techniques have proven useful to achieve control objectives in the case of restricted information structure, e.g. measurements taking values only in a finite set and/or feedback delivered to the actuators erratically. A major challenge in the research on control with limited information is the design of controllers which are distributed over a network. In this case, the controllers cooperate to achieve a

common goal but have access only to limited information provided by their neighbors. The notion of incremental generalized homogeneity has been recently introduced in the design of nonlinear stabilizing controllers. 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 outcome 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. Two aspects are at the bases of the more recent developments: a new representation of discrete-time dynamics, which provides a natural framework for comparing results from the continuous-time and discrete-time contexts, the concept of exact sampled model under feedback, which can be used to design piecewise continuous controllers in a direct digital context. From the solution to feedback linearization, stabilization, regulation, observer theory, new research lines are in the direction of Lyapunov and passivity based design, inverse optimal control and time delayed systems in discrete-time and under sampling. Particular attention is devoted to the settlement of executable algorithms for computing the proposed solutions. Possible improvements in optimal control problems by means of piecewise continuous cost functions are also under investigation as a new research line in the framework of nonlinear switching control methods. This kind of approach brings to significant improvements when dealing with limited resources or under a high level decision process on the cost of the action or on the priority of the intervention. 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 of experience evaluation and control are nowadays classical problems 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 dynamics 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.

The applicative aspects of the research activities are carried out at the Systems and Control Laboratory, founded in 1995.

3.6.3 Robotics

Research lines:

- Robot Modeling, Planning, and Control
- Vision-based Control
- Sensor-based Planning and Exploration
- Physical Human-Robot Interaction
- Mobile Robots and UAVs
- Humanoid Robots
- Networked Robots

Members: Alessandro De Luca (leader), Leonardo Lanari, Giuseppe Oriolo, Marilena Vendittelli.

PhD Students: Khaled Al Khudir, Barbara Barros Carlos, Gabriele Buondonno, Daniele De Simone, Paolo Ferrari, Marco Ferro, Maram Khatib, Nicola Scianca.

Post Docs: Massimo Cefalo, Marco Cagnetti, Claudio Gaz, Emanuele Magrini, Valerio Modugno.

The Robotics group at DIAG, and the associated Robotics Laboratory, 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 (in particular, with 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 servoing; control and visual servoing 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 research activities undergo experimental validation in our Robotics Laboratory. The current equipments 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 also have multiple RGB-D sensors and two 6D F/T sensors (Mini45 by ATI). In the past, we have designed and built a two-link flexible manipulator (FlexArm) and a differentially-driven wheeled mobile robot (SuperMARIO).

Projects:

- *COMANOID, Multi-Contact Collaborative Humanoids in Aircraft Manufacturing* - January 2015–December 2018 (RIA H2020-ICT-2014-1, 645097).
- *SYMPLEXITY, Symbiotic Human-Robot Solutions for Complex Surface Finishing Operations* - January 2015–December 2018 (IA H2020-FoF-2014, 637080).

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