DIS - Research Groups

Algorithm Engineering
Artificial Intelligence
Data and Knowledge Bases
Distributed Systems
Programming Languages and Methodologies

Biomedical Systems
Hybrid Systems
Identification and Optimal Control
Nonlinear Systems
Robotics

Combinatorial Optimization
Nonlinear Optimization
Industrial Economics
Industrial Organization and Management

DIS - Research Laboratories

Computer Science Laboratory
Network Control Laboratory
Operations Research Laboratory
Robotics Laboratory
Systems and Control Laboratory

DIS - Ph.D. Programs

Bioengineering
Computer Engineering
Operations Research
System Engineering

Dipartimento di Informatica e Sistemistica
"Antonio Ruberti"

Università di Roma "La Sapienza"
Via Eudossiana, 18 - 00184 Roma
http://www.dis.uniroma1.it

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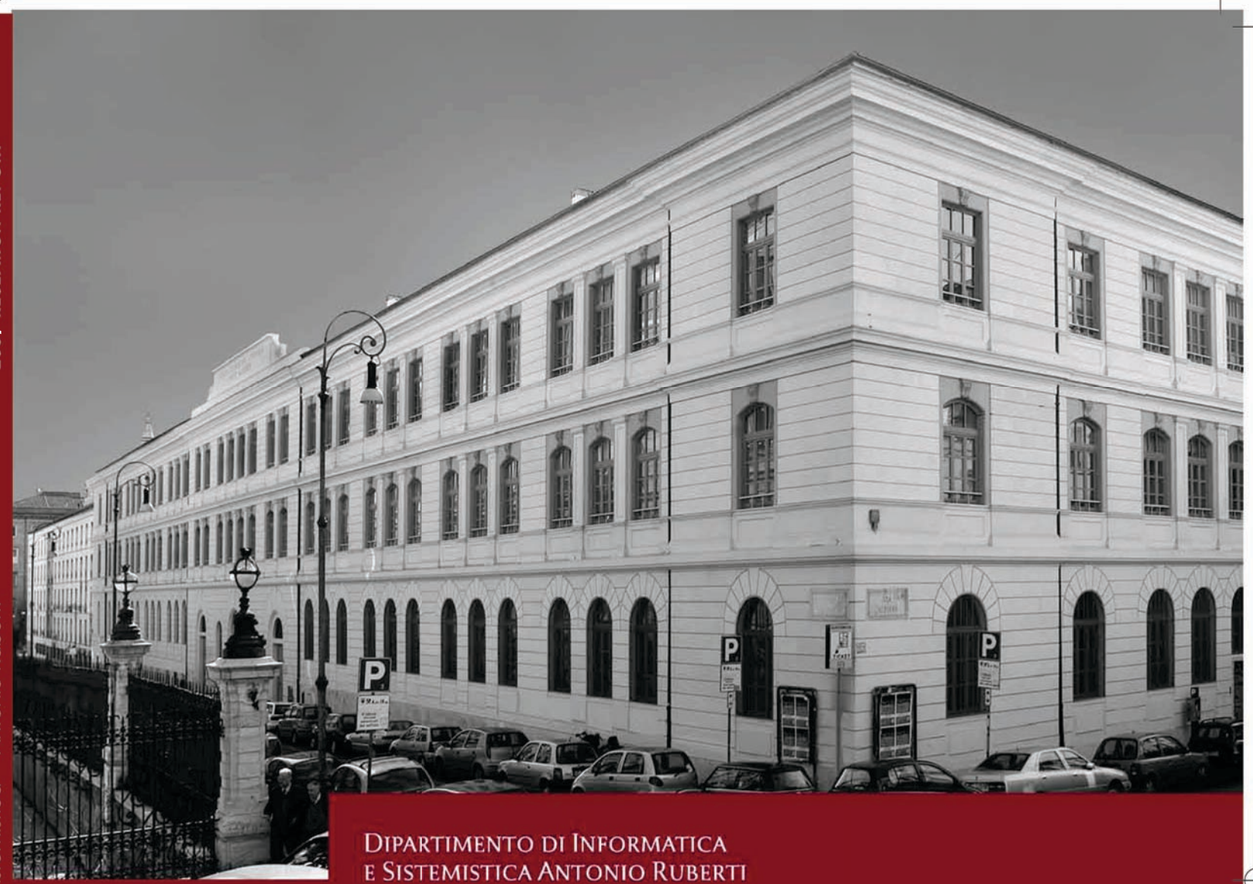
Dipartimento di Informatica e Sistemistica "Antonio Ruberti"

2007 RESEARCH REPORT



DIPARTIMENTO DI INFORMATICA
E SISTEMISTICA ANTONIO RUBERTI

SAPIENZA
UNIVERSITÀ DI ROMA

Research report 2007

www.aracneeditrice.it
info@aracneeditrice.it

via Raffaele Garofalo, 133 A/B
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Dipartimento di Informatica e Sistemistica Antonio Ruberti
Sapienza Università di Roma

Research report 2007

Dipartimento di Informatica e Sistemistica Antonio Ruberti

The present address of the Dipartimento di Informatica e Sistemistica Antonio Ruberti (Department of Computer and Systems Science, hereafter DIS) is:

DIS – Sapienza Università di Roma
Via Ariosto 25
00185 Roma, Italia

T +39 06 77274140
F +39 06 77274129

Web site: `http://www.dis.uniroma1.it`

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1 Introduction

The present report provides an overview of the research carried out at the Department of Computer and Systems Science Antonio Ruberti (DIS) of the Sapienza University of Rome, during the year 2007.

DIS 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 DIS 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.

DIS is a center for research and education at the undergraduate and graduate levels. Strong research groups exist in computer, systems, and management sciences. Basic research is the main goal of DIS, 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 DIS in 2007 consists of 31 full professors, 19 associate professors, and 15 assistant professors (ricercatori). They provide education at the undergraduate and graduate levels to several programs of the School of Engineering at Sapienza, with main responsibility in the curricula in informatics, systems and control sciences, and management. The teaching activity is not illustrated in this report; a description may be found be found at `http://www.dis.uniroma1.it/students.html`

Furthermore, DIS offers two Ph.D. programs, and cooperates with two Ph.D. programs offered by other departments. They are briefly described in Section 2 of this report, which is devoted to the general information.

The main research areas of DIS are:

- Computer science
- Systems science
- Management science

This is reflected in the structure of Section 3, where the main research lines are described for each area, together with the list of people involved, and the collection of publications appeared in 2007.

2 General Information

2.1 Location

The present location of DIS is the building known as Silvio Pellico, at Via Ariosto 25, near Piazza Dante in Rome.

DIS is on the web at `http://www.dis.uniroma1.it`.

2.2 Facilities

Library

The DIS library was first established in 1970 at the Istituto di Automatica. In 2007 the library moved to the new building at Via Ariosto 25, where two reading rooms are available for users. Approximately 11,000 books and conference proceedings, plus 392 journals subscriptions (94 of which active), and 784 on-line journals are currently available. The DIS library provides the department with access to information in its many formats in order to support teaching, learning, research, and service functions. The library facilities are also available to non-members of the Department, and students.

The library provides resources and services in an environment that fosters free and open enquiry, and serves as a catalyst for the interpretation, integration and application of knowledge in learning and research. It also fosters the cultural growth in the department and in the wider community.

During the year 2007, the DIS library continued the organization of the series of invited lectures *Incontri al Chiostro*, under the supervision of Professor Claudio GORI GIORGI. The lecturers of 2007 were:

Giorgio KOCH	Uguali e diversi	Feb. 9, 2007
Achille VARZI	Semplicità insormontabili	Mar. 8, 2007
Douglas HOFSTADTER	I am a strange loop (Anelli nell'Io)	Mar. 2, 2007
Alberto OLIVERIO	Come nasce un'idea	Mar. 19, 2007
Edoardo BONCINELLI	La magia della scienza	Apr. 17, 2007
Giorgio PARISI	La chiave, la luce e l'ubriaco. Come si muove una ricerca scientifica	Apr. 23, 2007
John MCCARTHY	The well-designed child	Sept. 27, 2007

Laboratories

DIS hosts several research and educational laboratories. The following list reports name, location, purpose, and the person in charge for each of them.

ALCOR - Cognitive 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 security systems.

Web: http://www.dis.uniroma1.it/∼alcor
Head Fiora PIRRI

Algorithms Engineering Laboratory
Via Ariosto 25 - wing B1
The laboratory is devoted to the engineering and the experimental performance analysis of combinatorial algorithms and their applications.
Web: http://www.dis.uniroma1.it/∼ae
Head Andrea VITALETTI

Automation Laboratory
Via Ariosto 25 - basement
The laboratory is devoted to the training of students on the design and realization of simple control systems.
Head Claudio GORI GIORGI

DAMSO Laboratory
Via Ariosto 25 - basement
The laboratory aims at developing models and testing efficient algorithms for processing real world data from industrial and biosystems engineering.
Head Alberto DE SANTIS

DASI Laboratory
Via Ariosto 25 - room 213, wing B2
The laboratory is devoted to the development of software research prototypes for service-based and data-integration distributed systems.
Web: http://www.dis.uniroma1.it/∼dasilab
Head Maurizio LENZERINI
Organization Massimo MECELLA

Joint Lab on Security Research
(Sapienza Innovazione)
Via Ariosto 25 - wing B1
The Joint-Lab on security research has the mission to create a critical mass of researchers of La Sapienza around system and software security in complex environments. Results of research of the joint-lab are heavily oriented toward innovation and the creation of early stage technology companies.
Web: http://www.dis.uniroma1.it/∼labsec
Head Roberto BALDONI

Management Engineering Laboratory
Via Ariosto 25 - room 122 and 123, wing A1
The laboratory is devoted to the development of mathematical models and solution algorithms for Management Engineering problems.

Web: `http://www.dis.uniroma1.it/~or/lab.html`
Head Massimo ROMA

Middleware Laboratory - MIDLAB
Via Ariosto 25 - wing B1
The primary goal of MIDLAB is to support leading-edge research and development on middleware, bridging the gap between the latest research results and the current technologies.
Web: `http://www.dis.uniroma1.it/~midlab`
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

Robotics Laboratory
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.dis.uniroma1.it/~labrob`
Head Giuseppe ORIOLO

SPQR - Soccer Player Quadruped Robots
Via Ariosto 25 - room 219, wing A1
The laboratory of the legged (four-legged and humanoid) teams participating in RoboCup.
Web: `http://www.dis.uniroma1.it/~spqr`
Head Daniele NARDI

Software Development (Thesis Students) Laboratory
via Ariosto 25 - rooms A1 and A2
The laboratory is devoted to the training of students on the design and implementation of software systems.
Head Massimo MECELLA

Systems and Control Laboratory
Via Ariosto 25 - basement
The laboratory is devoted to the development and experimental verification of new control strategies.
Web: `http://sistemi.ing.uniroma1.it/`

Head Salvatore MONACO

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.dis.uniroma1.it/cms/`
Head Andrea VITALETTI

In addition, DIS runs a research Lab in cooperation with "Istituto Superiore Antincendi," and located on their premises:

SIED: Intelligent Systems for Emergencies and Civil Defense
Via del Commercio, 13 (Istituto Superiore Antincendi) Roma.
The goal of SIED is to develop methodologies, techniques and tools to be used in rescue operations.
Web: `http://sied.dis.uniroma1.it/`
Head Daniele NARDI.

Additional information on the DIS laboratories may be found at `http://www.dis.uniroma1.it/`.

Educational laboratories

DIS manages two educational laboratories of the School of Engineering, used for hands-on teaching and for self-studying. The laboratories are named after Paolo Ercoli, the founder of the Computer science component of the department. Educational laboratories are on the web at the address `http://www.dis.uniroma1.it`

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.

2.3 People

Director
Luigia CARLUCCI AIELLO

Administration head
Maria Pia VANDILLI

Faculty

Professors

Giorgio AUSIELLO
Roberto BALDONI
Stefano BATTILOTTI
Carlo BRUNI
Luigia CARLUCCI AIELLO
Tiziana CATARCI
Bruno CICIANI
Giacomo CIOFFI (retired Nov. 2007)
Alessandro DE CARLI
Giuseppe DE GIACOMO
Alessandro DE LUCA
Francesco DELLI PRISCOLI
Gianni DI PILLO
Francisco FACCHINEI
Claudio GORI GIORGI
Luigi GRIPPO
Alberto ISIDORI
Maurizio LENZERINI
Stefano LEONARDI
Claudio LEPORELLI
Stefano LUCIDI
Alberto MARCHETTI SPACCAMELA
Salvatore MONACO
Umberto NANNI
Daniele NARDI
Alberto NASTASI
Maria Luisa PETIT TARASCON
Fiora PIRRI
Francesca SANNA RANDACCIO
Antonio SASSANO
Marco SCHAERF

Associate professors

Luca BENVENUTI
Fabrizio D'AMORE
Alberto DE SANTIS
Lorenzo FARINA
Domenico LAISE
Leonardo LANARI
Paolo LIBERATORE
Carlo MANNINO
Giuseppe ORIOLO
Laura PALAGI
Pier Luigi PICCARI
Francesco QUAGLIA
Pierfrancesco REVERBERI
Massimo ROMA
Riccardo ROSATI
Serenella SALINARI
Silvio SALZA
Giuseppe SANTUCCI
Marco TEMPERINI

Assistant professors (ricercatori)

Alessandro AVENALI
Luca BECCHETTI
Roberto BERALDI
Claudia CALIFANO
Claudio DE PERSIS
Camil DEMETRESCU
Paolo DI GIAMBERARDINO
Daniela IACOVIELLO
Luca IOCCHI
Domenico LEMBO
Giorgio MATTEUCCI
Massimo MECELLA
Roberta SESTINI
Marilena VENDITTELLI
Andrea VITALETTI

Contract professors
Fabio CELANI

Staff

Research associates and post docs

Enrico BERTINI
Silvia CANALE
Antonella CHIRICHIELLO
Vincenzo BONIFACI
Toni MANCINI
Luigi FREDA
Sara MATTIA
Raffaella MATTONE
Veronica PICCIALLI
Antonio PIETRABISSA
Sara TUCCI
Antonella POGGI
Marco RUZZI
Davide GUGLIELMO
Stefano SASSONE
Andrea USAI
Alessandro FARINELLI
Claudia FERRONE
Giorgio GRISETTI
Giorgio KOCH
Alessia MILANI
Leonardo QUERZONI
Piotr SANKOSKY
Fabiano SARRACCO

Administration staff
Amelia ARRICALE
Antonietta CANGELLI
Beatrice DE CARLO
Maria Grazia GIACON (retired Oct. 2007)
Tiziana VALENTINI
Maria Pia VANDILLI

Technical staff
Anna Paola DI RISIO (part time)
Giuseppe FILACI
Tiziana TONI

Auxiliary services
Pia BONANNI
Antonio SIMEONI

Librarian
Laura ARMIERO

Telephone numbers, e-mail addresses and home pages of people at DIS are available on the web at `http://www.dis.uniroma1.it/`.

2.4 Doctoral programs

DIS directly hosts the Ph.D. programs in Computer engineering and in Systems engineering. Moreover, DIS cooperates in the Ph.D. programs in Bioengineering, hosted by DEIS (the Department of Electronic, Computer and System Sciences) of the University of Bologna and in Operations research, hosted by the Department of Probability and Statistics of the Sapienza University of Rome.

Bioengineering

DIS participates in the Ph.D. program in Bioengineering coordinated by the department DEIS of the University of Bologna.
The research topics are: Modeling of biomedical systems, processing of biomedical data, signals and images, biomedical instrumentation, medical informatics, biomechanics, prostheses, and bio-materials.

Ph.D. students (working at DIS)

XXI course

MATTEI Eugenio

Computer engineering

The council of professors of the Ph.D. program in Computer engineering is coordinated by Maurizio LENZERINI.
The research topics are: 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.

Ph.D. students

XX course	XXI course	XXII course	XXIII course
ADNAN NOOR Mian	BELARDINELLI Anna	ACCATTOLI Beniamino	CARBONE Andrea
CHIRICHELLO Antonella	DE LEONI Massimiliano	BLOISI Domenico	COLESANTI Ugo Maria
FRATARCANGELI Marco	MARCHETTI Luca	BONOMI Silvia	DI GIOIA Matteo
RIBICHINI Andrea	PASCUCCI Alessio	BORDINO Ilaria	LEONETTI Matteo
UGAZIO Giorgio	PATRIZI Fabio	CALISI Daniele	MARRA Stefano
ZIPARO Vittorio Amos	SCIPIONI Sirio	GOMEZ Valero Alberto	PIZZOLI Matia
	SETTEMBRE Giuseppe Paolo	HUMAYOUN Shah Rukh	RANDELLI Gabriele
	TIPALDI Gian Diego	LAMANNA Domenico	
		PELLEGRINI Stefano	

Operations research

The council of professors of the Ph.D. program in Operations research is coordinated by the Department of Probability and Statistics of Sapienza.
The research topics are: Combinatorial optimization, nonlinear programming, network design, neural networks, logistics, management systems, and industrial systems economy.

Ph.D. students (working at DIS)

XX course	XXI course	XXII course
RISI Arnaldo	RINALDI Francesco	D'ANDREAGIOVANNI Fabio

Systems engineering

The council of professors of the Ph.D. program in Systems engineering is coordinated by Carlo BRUNI.
The research topics are: Systems theory, automatic control, nonlinear systems, intelligent control, robotics, flexible manufacturing systems, biosystems, modelling, identification, optimal control, and resource management for wireless systems.

Ph.D. students

XX course	XXI course	XXII course	XXIII course
BALDESI Gianluca	FABBRI Filippo	ASNAGHI Simone	MARCHIONNI Luca
CAVARISCHIA Leonardo	GABRIELE Simone	CASTRUCCI Marco	ORSINI Giuseppe
CHERUBINI Andrea	MIGNANTI Silvano	DI GIORGIO Alessandro	PIMPINELLA Laura
ROBUFFO GIORDANO Paolo	MERCURIO Andrea	FRANCHI Antonio	RODRIGUEZ Filippo
SURACI Vincenzo		GENTILI Enrico	RUSSO Valentina
SANTORO Gianfranco			VEROLI Marco

Visiting scientists

Valerio BAIOCCHI
Michel BANARTRE, IRISA-INRIA, France
Daniel BIENSTOCK
Jan Oskar CHOMICKI, University at Buffalo, NY, USA
Yael DUBINSKY, Technion, Israel
Amos FIAT
Herbert FREEMAN, Rutgers University, NJ, USA
Norberto Mauricio GRZYWACZ, University of Southern California, CA, USA
Torben HAGERUP
Orin Knight HARGRAVES
Michel KIFER, State University of New York at Stony Brook, NY, USA
Alexander KLEINER
Peter KORTEWEG
Eiji KOYANAGI
Yves LESPERANCE, York University, Ontario, Canada
Miroslaw MALEK, Humboldt University, Berlin, Germany
Garg NAAVEN
Marie Dorothée NORMAND-CYROT , L2S-CNRS-Supélec, France
Christos PAPADIMITRIOU
David POWELL, LAAS-CNRS, France
Michel RAYNAL, IRISA-INRIA, France
Piotr SANKOSKY
Sebastian SARDINA, RMIT University, Melbourne, Australia
Raymond SHEH
Mohit SINGH
Eric Kuo-Tai TORNG
Takashi TSUBOUCHI
Constantinus Peter VAN HOESEL
Moshe Y. VARDI, Rice University, TX, USA
Yutaka YAMAMOTO

2.5 Contracts

DIS carries on its research on contracts with public funding agencies and companies. Some of them go on over more than one year. Contractor, value in Euro, title, project leader and duration of each contract are detailed in the list below. The titles of the contracts with Italian bodies are reported in Italian.

Contracts with the European Union (E.U.)

- E.U., 205.500, TONES, Thinking Ontologies, G. De Giacomo (up to 08/31/08)
- E.U., 236.500, SATSIX, Satellite-based communications system within IPv6 networks, F. Delli Priscoli (up to 05/31/08)
- E.U., 193.520, AEOLUS, Algorithmic principles for building efficient overrlay computers, A. Marchetti Spaccamela
- E.U., 121.365, CYBERWALK, The CyberCarpet: Enabling Omni-directional Walking in Virtual Worlds, A. De Luca (up to 03/31/08)
- E.U., 540.000, DELIS, Dynamically Evolving Large Scale Information Systems, S. Leonardi (up to 03/31/2008)
- E.U., 100.237, VIEW-FINDER, Vision and Chemiresistor Equipped Web-connected Finding Robots, F. Pirri (up to 11/30/09)
- E.U., 240.000, SEMANTICGOV, Providing Integrated Public Services to Citizens at the National and Pan-European level with the use of Emerging SemanticWeb Technologies, R. Baldoni (up to 12/31/08)
- E.U., 195.489, PHRIENDS, Physical Human-Robot Interaction: depENDability and Safety, A. De Luca (up to 09/30/09)
- E.U., 160.335, Resilience for Survivability in IST, R. Baldoni (up to 12/31/2008)
- E.U., 322.500, WORKPAD, An Adaptive Peer-to-Peer Software Infrastructure for Supporting Collaborative Work of Human Operators in Emergency/Disaster Scenarios, T. Catarci (up to 08/31/09)
- E.U., 54.420, PANORAMA, Pervasive Adaptation Network for the Organisation of the Research Agenda and The Management of Activities, A. Marchetti Spaccamela (signed on October 2007 - duration 01/01/08-12/31/2010)
- E.U., 200.000, FRONTS, Foundations of Adaptive Networked Societies of Tiny Artefacts, A. Marchetti Spaccamela. (signed in October 2007 - duration 01/01/08-12/31/2010)
- E.U., 256.500, P2P-NEXT, Next Generation Peer-to-Peer Content Delivery Platform, F. Delli Priscoli (signed in October 2007 - duration 01/01/08-12/31/2011)

Contracts with Italian Institutions

- CNR/POLITECNICO DI MILANO, 49.450, Architetture Software e Middleware per il supporto alle applicazioni in ambiente MANET, R. Baldoni (31.12.2007)
- CNR/POLITECNICO DI MILANO, 17.789, Progetto VICE, Definizione e realizzazione dei moduli didattici, Implementazione della piattaforma, coordinamento delle attività e disseminazione dei risultati, T. Catarci (31.12.07)

- MAE, 53.620, Post Earthquake emergency: Methods, Techniques and Support Instrumentation-Giappone, D. Nardi (December 2007)
- RCOST-UNISANNIO, 207.900, FISR Progetto INTERAGRO, Metodi e Strumenti per la supply chain INTEgRata nell'AGRO alimentare, A. Sassano (05.12.08)
- MIUR, 204.306, CELTIC - IMAGES Integrated multimedia architectures for next generation services, F. Delli Priscoli (30.06.07)
- MIUR, 380.800, APICE - Algoritmi per la Pianificazione Integrata e Controllo di reti wireless Eterogenee, F. Delli Priscoli (30.06.09)
- MIUR, 36.500, Algoritmi per strutture informative di grandi dimensioni e 'data streams', G. Ausiello (31.01.09)
- MIUR, 11.500, Studio, progetto e realizzazione di algoritmi efficienti di classificazione mediante reti neurali artificiali di immagini di provini metallografici di ghisa sferoidale; modelli dinamici basati su reti neurali artificiali di fenomeni di frattura, A. De Santis (31.12.07)
- MIUR, 19.700, Modelli e metodi per l'analisi degli investimenti e delle scelte tecnologiche nei settori dell'energia elettrica e delle telecomunicazioni, C. Leporelli (31.12.07)
- MIUR, 48.000, ESTEEM: Emergent Semantics and Cooperation in multi-knowledge Enviroments - Metodi e strumenti avanzati per la collaborazione semantica in comunità virtuali su web, T. Catarci (31.12.07)
- MIUR, 39.800, PRIN: Problemi e Metodi Innovativi nell'Ottimizzazione Nonlineare, G. Di Pillo (up to 30/01/2008)

Contracts with companies

- SELEX 15.000, Progetto e sperimentazione di procedure di elaborazione di dati audiovisivi per l'analisi comportamentale di soggetti in ambienti pubblici, A. De Santis
- TERNA S.p.A. 50.000, Servizio Tecnico per studi. Regolazione dei parametri e fornitura di algoritmi WAMS-ORDINE 3000023135, S. Monaco
- C.M. SISTEMI S.p.A. 50.000, Studio di metodi e linguaggi per la rappresentazione e descrizione di ontologie, M. Lenzerini

2.6 Seminars

Many scientists are invited to deliver seminars at DIS each year. Below is a list of seminars for the year 2007, in chronological order.

- February 7th, Torben Hagerup, University of Augsburg
  A very practical algorithm for the two-paths problem in 3-connected planar graphs
- March 1st, Serge Abiteboul, INRIA-Futurs et LRI-Université de Paris 11
  Indexing and XML query processing in a P2P network
- April 3rd, Paolo Missier, University of Manchester
  Modelling and computing the quality of information in e-science
- April 11th, Mads Nygaard, Norwegian University of Science and Technology
  Mobility: Transactional issues in collaborative works

- April 16th, Alessandro Saffiotti, Orebro University
  The PEIS-Ecology Project: A progress report
- April 26th, Fabio Ganovelli, CNR - Pisa
  Interactive rendering of large datasets in commodity platforms
- April 26th, Andrea Maiolo, Industrial Light and Magic, California
  3D character rigging in movie industry
- June 30th, Stefano Zatti, European Space Agency
  La sicurezza delle attività spaziali
- July 2nd, Jan Chomicki, University at Buffalo and Warsaw University
  Consistent query answers in inconsistent databases
- July 3rd, Michael Kifer, State University of New York at Stony Brook
  Reasoning about the behavior of semantic web services with concurrent transaction logic
- July 5th, Anna Belardinelli, Sapienza University of Rome
  Statistical learning for data mining
- July 5th, Gian Diego Tipaldi, Sapienza University of Rome
  Dynamic bayesian networks: modeling, inference and learning
- September 19th, Torben Hagerup, University of Augsburg
  Fun with shortest paths
- October 15th, Gabor Simonyi, Budapest University of Technology and Economics
  Perfect graphs: a tutorial
- November 5th, Yann Busnel, Université Rennes 1
  Solist: A lightweight multi-overlay structure for wireless sensor networks
- November 16th, Giulia Piaggio, Istituto Nazionale Tumori Regina Elena, Roma
  Integrazione di informazioni biomolecolari per lo studio e la terapia dei tumori: nuovi approcci sperimentali per mappare il legame di complessi proteici sul genoma umano
- December 4th, Fabiano Botta, Sapienza University of Rome
  Relazioni tra meccanismi di orientamento spaziale attentivo e memoria di lavoro visuo-spaziale
- December 4th, Valerio Santangelo, Sapienza University of Rome
  Integrazione multisensoriale e orientamento automatico dell'attenzione spaziale
- December 6th, Norberto Grzywacz, University of Southern California
  L'adattamento sensoriale cerebrale segue leggi di controllo ottimo?

In addition, the department organizes a series of seminars in cooperation with the Department of Computer Science. Below is a selection of the seminars of the series.

- January 29th at DI, Christos Papadimitriou, University of California
  Computing equilibria
- February 12th at DI, Stefano Leonardi, Sapienza, University of Rome
  Efficient cost-sharing mechanisms for prize-collecting steiner forest
- February 19th at DI, D. Manivannan, University of Kentucky
  A routing protocol with selective forwarding for mobile ad-hoc networks
- March 5th at DI, Naveen Garg, Indian Institute of Technology
  Online integer packing

- March 19th at DIS, Anupam Gupta, Carnegie Mellon University
  Oblivious network design
- April 2nd at DI, Paolo Franciosa, Sapienza, University of Rome
  Small stretch (alpha, beta) - spanners in the streaming model
- May 7th, Alberto Apostolico, Georgia Tech
  Monotony and surprise: Conservative approaches to pattern discovery

3 Research

3.1 Computer Science

3.1.1 Algorithm Engineering

The research activity of the group of Algorithm Engineering (AE) is concerned with the design, the engineering, the theoretical and experimental performance analysis of combinatorial algorithms for problems arising in modern Computer Systems and Networks, and in applications related to complex resource management problems. Our main research interests deal with the solution of optimization problems and the design of efficient data structures, with special emphasis on applications involving massive data sets. In particular we concentrate on:

- algorithms that perform efficiently in a dynamically changing environment;
- models and efficient, scalable algorithms for the analysis of large scale information networks;
- models and methodologies for the analysis and design of algorithms for information retrieval in large scale networks;
- the design and analysis of approximation algorithms for NP-hard optimization problems;
- the design of on-line algorithms that work with incomplete information on the input instance;
- the design and analysis of algorithms for efficient resource management in the presence of rational, selfish users;
- models for industrial network design and management.

The AE group is currently cooperating with several prestigious research institutions: Max Planck für Informatik (Saarbrücken, Germany), CTI-Patras and University of Athens (Greece), ETH (Zurich, Switzerland), Université de Paris (Dauphine, France), Tel-Aviv University (Israel), AT&T - Research Labs (Florham Park, NJ, USA), ICSI-Berkeley (USA), Brown University (Providence, RI, USA), Carnegie-Mellon University (Pittsburgh, PA, USA), Microsoft Research (Mountain View, CA, USA), Yahoo Research (Barcelona, Spain).

The AE group is presently involved in the following research projects: EU Contract 001907 "Dynamically Evolving Large Scale Information Sytems" (DELIS); EU/IST Integrated Project IP-FP6-015964 AEOLUS, "Algorithmic Principles for Building Efficient Overlay Computers"; MIUR National Project MAINSTREAM: "Algoritmi per strutture informative di grandi dimensioni e data streams"; MIUR Firb international Italian-Israelian cooperation RBIN047MH9 project.

Faculty members Giorgio AUSIELLO, Luca BECCHETTI, Fabrizio D'AMORE, Camil DEMETRESCU, Stefano LEONARDI, Alberto MARCHETTI-SPACCAMELA, Umberto NANNI, Andrea VITALETTI.
Post-docs Luca ALLULLI, Vincenzo BONIFACI, Luigi LAURA, Fabiano SARRACCO.
PhD students Ilaria BORDINO, Ugo COLESANTI, Andrea RIBICHINI.
Visitors Piotr SANKOWSKI.

Dynamic and adaptive graphs algorithms. In this area, major emphasis has been devoted to the analysis and design of algorithms for dynamically evolving graphs and connectivity, with a focus on the efficient use of the memory hierarchy.

In [3], the authors survey algorithms for shortest paths in dynamic networks. They make an effort to abstract some combinatorial and algebraic properties, and some common data-structural tools that are at the base of those techniques. This allows them to present some of the newest results in a unifying framework so that they can be better understood and deployed also by non-specialists.

[7] presents a cache-oblivious algorithm for computing shortest paths in undirected graphs with non-negative edge weights. The algorithm makes an efficient use of memory resources, in particular with respect to the overall number of block transfers between first level memory and cache as a function of the network size. The main challenge in obtaining this result, and a serious one, is a data structuring problem: how to make the hot pool work for arbitrary block sizes.

Efficient algorithms for large scale network analysis. The analysis of large scale information networks (e.g. the Web or those arising in P2P applications) poses challenges that require new algorithmic solutions. Our research in this area has focussed on the development of efficient analysis techniques, requiring sublinear (typically, logarithmic) time per update operation and minimizing access to secondary storage.

In [8] the authors present deterministic algorithms for computing small stretch spanners in the streaming model. In [10] the authors investigate how parallel algorithms can be turned into efficient streaming algorithms for several classical combinatorial problems, leading to new techniques for processing massive data sets in external memory. In [9] the authors extend previous work on counting triangles on datastreams to the problem of estimating clustering indexes on graphs of very large size. In [25], the authors generalize previous techniques for counting undirected triangles in large graphs, proposing data-stream algorithms that approximate the number of all minors of three and four vertices in directed and undirected graphs. The book chapter [19] provides a review of challenges and algorithmic solutions in this area.

Algorithms for information retrieval in large scale networks. We have continued our effort in the design, implementation and analysis of algorithmic techniques for the retrieval of information in massive data sets, in particular the Web and other information networks.

In [24] the authors provide the results of some preliminary analysis perfomed on Web temporal data. They also study the dynamics of the largest connected components and compute statistics about birth and death of both nodes and edges, with the aim of quantifying the rate and the amount of change within the hostgraph. In [4], the authors extensively report on work done in previous years on the mining of the baseline features of the Webgraph. Web spam detection and demotion techniques have also been applied to reputation management in P2P networks. In [26] it is investigated the role of users' negative feedback in order to device decentralized reputation management mechanisms more effective than algorithms exclusively based on positive assessments.

Optimization algorithms for NP-hard problems. In the design and analysis of approximation algorithms for NP-hard problems, we have concentrated on resource allocation and network design problems.

In [1] the authors consider multicommodity rent-or-buy (MROB) network design problems. In this article the authors give a 6.828-approximation for the MROB problem by refining the algorithm of Gupta et al. and simplifying their analysis. In [5] the authors study budgeted variants of

classical cut problems: the Multiway Cut problem, the Multicut problem, and the k-Cut problem, and provide approximation algorithms for these problems.

On-line algorithms. We have continued our investigation of algorithms for on-line problems arising in several optimization scenarios.

In [2], the author considers an online server routing problem, in which an agent moves in a network in order to process incoming requests at the nodes. This general framework is suitable to model a number of problems of interest in overlay networks, in which the agents represent (for example) a limited number of instances of an application running in a global computer. In [22], the authors consider two on-line versions of the asymmetric traveling salesman problem with triangle inequality. For the homing version, in which the salesman is required to return in the city where it started from, they give a $(3 + \sqrt(5))/2$-competitive algorithm and prove that this is best possible. In [23], the authors study the problem of data aggregation in sensor networks to minimize maximum energy consumption under latency constraints on sensed data delivery. They consider both the case in which sensor nodes are synchronized or not, in some cases showing optimality of the proposed algorithms. In [6] the authors consider the problem of optimizing the total flow time of a stream of jobs that are released over time in a multiprocessor setting. The authors first prove that when preemption is allowed, Shortest Remaining Processing Time (SRPT) achieves a logarithmic approximation for the total flow time. They also provide a matching lower bound on the competitive ratio of any randomized algorithm for the on-line problem in which jobs are known at their release times.

Algorithmic game theory. Extensive reserach was devoted to the design and analysis of algorithms and mechanisms for the efficient allocation of resources and the fair allocation of costs in the presence of rational, selfish users.

In [12], the authors present a simple 3-budget-balanced and group-strategyproof mechanism for the game theoretical version of Prize-collecting Steiner forest problem. They also show that the proposed mechanism computes client sets whose social cost is worst that the minimum social cost for at most a polylogarithmic factor. In [11] the authors present the first primal-dual 8-approximation algorithm for the subscription pricing problem. The authors also provide bounds on the inefficiency of the proposed mechanism. In [13] the authors study how the price of anarchy of network formation games with Shapley cost allocation is affected by allowing locally coordinated coalitions of players.

Models for industrial network design and management. We devoted some attention to design and performance issues in industrial software/network architectures.

In [15] authors show analytically the Ethernet non deterministic aspect and propose a new solution that allows using Ethernet in industrial real time environments. Architectural Design, as in many other contexts, requires contribution from several experts, each with his/her own knowledge, experience, tools, and a source of possible problems, constraints, and suggestions. A collaborative approach consists in creating an opportunity for each expert to provide a contribution to the design process. In [14] the authors show how such a collaboration approach to Architectural Design would be fostered by adopting suitable models and collaboration environments.

Journals

[1] Becchetti L., Könemann J., Leonardi S. and Pal M. Sharing the cost more efficiently: Improved approximation for multicommodity rent-or-buy. *ACM Transactions on Algorithms*, **3**(2), 2007.

A preliminary version appeared in proceedings of the ACM SIAM Symposium on Discrete Algorithms, 2005.

[2] Bonifaci V. An adversarial queueing model for online server routing. *Theoretical Computer Science*, **381**(1-3), pp. 280–287, 2007.

[3] Demetrescu C. and Italiano G. F. Algorithmic Techniques for Maintaining Shortest Routes in Dynamic Networks. *Electronic Notes in Theoretical Computer Science*, **171**(1), pp. 3–15, 2007.

[4] Donato D., Laura L., Leonardi S. and Millozzi S. The Web as a graph: How far we are. *ACM Transactions on Internet Technnology*, Volume 7, Number 1, 2007.

[5] Engelberg R., Könemann J., Leonardi S. and Naor J. Cut problems in graphs with a budget constraint. *Journal of Discrete Algorithms*, Volume 5(2), pages 262 – 279, 2007.

[6] Leonardi S. and Raz D. Approximating total flow time on parallel machines. *J. Comput. Syst. Sci.*, Volume 73(6), pages 875 – 891, 2007.

Conference proceedings

[7] Allulli L., Lichodzijewski P. and Zeh N. Improved Cache-Oblivious Single-Source Shortest Paths For Small Edge Weights. *Proceedings of the 18th Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'07)*, 2007.

[8] Ausiello G., Demetrescu C., Franciosa P. G., Italiano G. F. and Ribichini A. Small Stretch Spanners in the Streaming Model: New Algorithms and Experiments. *Proceedings of the 15th Annual European Symposium on Algorithms (Engineering and Applications Track)*, pp. 605–617, 2007.

[9] Buriol L. S., Frahling G., Leonardi S. and Sohler C. Estimating Clustering Indexes in Data Streams. *Proceedings of the 15th Annual European Symposium on Algorithms, Lecture Notes in Computer Science*, pages 618-632, Springer, 2007.

[10] Demetrescu C., Escoffier B., Moruz G. and Ribichini A. Adapting Parallel Algorithms to the W-Stream Model, with Applications to Graph Problems. *Proceedings of the 32nd International Symposium on Mathematical Foundations of Computer Science (MFCS 2007)*, pp. 194–205, 2007.

[11] Goyal V., Gupta A., Leonardi S. and Ravi R. Pricing tree access networks with connected backbones. *Proceedings of the 15th Annual European Symposium on Algorithms*, Volume 4698 of Lecture Notes in Computer Science, pages 498 – 509, Springer, 2007.

[12] Gupta A., Könemann J., Leonardi S., Ravi R., and Schäfer G.. An efficient cost-sharing mechanism for the prize-collecting steiner forest problem. *Proceedings of ACM-SIAM Symposium on Discrete Algorithms (SODA 2007)*, pages 1153 – 1162, 2007.

[13] Leonardi S. and Sankowski P. Network formation games with local coalitions. *Proceedings of the ACM conference on Principles Of Distributed Computing (PODC) 2007*, pages 299 – 305, 2007.

[14] Nanni U. and Santacaterina A. Cokaad: A framework for collaborative architectural design. *Collaborative Architectural and Building Design (CollABD 2007), December 13-15th, 2007, Rome, Italy*, 2007.

[15] Santacaterina A., Di Biagio C., Pennella G. and Nanni U. The Hard Real-Time Problem on Ethernet. *Communication Systems and Networks (CSN 2007), August 29 - September 31, 2007, Palma De Mallorca, Spain, Acta Press*, 2007.

Articles in books

[16] Ausiello G. and Paschos V. Th. Reductions that Preserve Approximability. *Handbook of Approximation Algorithms and Metaheuristics*, Teofilo F. Gonzales Ed., Chapman & Hall/CRC, 2007.

[17] Ausiello G. and Paschos V. Th. Differential Ratio Approximation. *Handbook of Approximation Algorithms and Metaheuristics*, Teofilo F. Gonzales Ed., Chapman & Hall/CRC, 2007.

[18] Ausiello G., Bonifaci V., Leonardi S. and Marchetti-Spaccamela A. Prize-Collecting Traveling Salesman and Related Problems. *Handbook of Approximation Algorithms and Metaheuristics*, Teofilo F. Gonzales Ed., Chapman & Hall/CRC, 2007

[19] Demetrescu C. and Finocchi I. Handbook of Applied Algorithms: Solving Scientific, Engineering, and Practical Problems, A. Nayak ed I. Stojmenovic eds., Chapter 8, *Algorithms for Data Streams*, John Wiley and Sons, 2007.

Book

[20] Demetrescu C. (ed.). Experimental Algorithms, Proceedings of the 6th International Workshop (WEA'07). *Lecture Notes in Computer Science*, vol. 4525, Springer Verlag, 2007.

Ph.D. thesis

[21] Bonifaci V. Models and Algorithms for Online Server Routing. *PhD thesis*, Sapienza University of Rome, Dipartimento di Informatica e Sistemistica, 2007.

Submitted papers, technical reports and others

[22] Ausiello G., Bonifaci V. and Laura L. The on-line asymmetric traveling salesman problem. *Journal of Discrete Algorithms*, , 2007. To appear. doi:10.1016/j.jda.2007.03.002.

[23] Becchetti L., Korteweg P., Marchetti-Spaccamela A., Skutella M., Stougie L. and Vitaletti A. Latency Constrained Aggregation in Sensor Networks. *ACM Transactions on Algorithms*, 2007. To appear.

[24] Bordino I., Castillo C., Donato D., Gionis A., and Leonardi S. Analyzing the evolving Web. *EU Project DELIS – Technical Report*, 2007.

[25] Bordino I., Donato D., Gionis A., and Leonardi S. Mining large networks with subgraph counting. *DELIS – Technical Report*, 2007.

[26] Donato D., Paniccia P., Selis M. and Leonardi S. Combine Transitive Trust with Negative Opinions for better Reputation in P2P Networks. *EU Project DELIS – Technical Report*, 2007.

3.1.2 Artificial Intelligence

The Artificial Intelligence (AI) research group is working on several aspects of AI. The research activities of the group are mainly oriented towards the following topics:

- Complexity of Reasoning
- Reasoning under Uncertainty
- Constraint-based Architectures for Planning and Scheduling
- Computer Vision and State Estimation
- Multi-robot and multi-agent systems

- Cognitive Robotics, learning and perception
- Constraint modelling and programming
- Computer Graphics

Main projects:
"Post-earthquake emergency: Methods, Techniques and Support Instrumentation" Scientific Cooperation Italy-Japan, Italian Ministry of Foreign Affairs - SIED Lab.
"ROBOtics for the CARE of elderly and disable people (ROBOCARE)" (Italian National Research Council) SIED Lab. and ISTC-CNR.
"Implementazione dell'architettura di supervisione del Robot Antartico di Superficie (RAS)" ENEA and ALCOR Lab.
"Flir-OWS" concerning the sensorial fusion between a laser range finder and a infrared camera for an obstacle avoidance system. Galileo Avionica (Finmeccanica) and ALCOR Lab.
"Stabilizzazione elettronica di immagini" deals with development and application of image stabilization techniques for cameras mounted on aerial vehicles. Galileo Avionica (Finmeccanica) and ALCOR Lab.
"Viewfinder"(IST-045541-VIEW-FINDER)[1] approved within the European Union FP6 "Advanced Robotics" call. In the last year has taken part in two meetings with the others European partners, and organized one that has been held in Rome in May (ALCOR Lab).
"Automatic Remote Grand Canal Observation System (ARGOS)", for distributed boat traffic monitoring in Venice's Grand Canal. - SIED Lab.

It's also worth mentioning that the AI group at DIS has a long term collaboration with the Planning and Scheduling Team of the ISTC-CNR, Rome lead by Amedeo Cesta, whose contribution is described in the section "Constraint-based architectures for planning and scheduling".

Group members

Faculty Members: Luigia CARLUCCI AIELLO, Luca IOCCHI, Paolo LIBERATORE, Daniele NARDI, Fiora PIRRI, Marco SCHAERF.

Post-docs: Andrea CARBONE, Alessandro FARINELLI, Toni MANCINI, Stefano MARRA, Francesco SCIALACQUA.

PhD Students: Anna BELARDINELLI, Domenico BLOISI, Daniele CALISI, Antonella CHIRICHIELLO, Marco FRATARCANGELI, Matteo LEONETTI, Alessio PASCUCCI, Fabio PATRIZI, Federico PECORA, Stefano PELLEGRINI, Matia PIZZOLI, Gabriele RANDELLI, Giuseppe Paolo SETTEMBRE, Gian Diego TIPALDI, Giorgio UGAZIO, Alberto VALERO, Vittorio Amos ZIPARO.

Visitors: Alberto FINZI, Thomas LUKASIEWICZ.

Complexity of reasoning Efficiency of AI systems is important for their success, as it is important in all engineering projects. If logic is to be used as the major tool for Knowledge Representation and Reasoning we have to deal with computational aspects. During the year 2007, the AI group continued the investigation on fundamental properties of complexity of reasoning, with the overall goal of designing computationally efficient and adequately expressive systems for Knowledge Representation and Reasoning. In particular, research has focused on default logic and propositional abduction. The main publications in this topic have been: [9, 10, 11].

[1] http://www.shu.ac.uk/mmvl/research/viewfinder/

Reasoning under Uncertainty. The research on reasoning under uncertainty focuses on probabilistic reasoning about actions and for the Semantic Web [18, 61, 72, 71, 70]. In particular, [64] presents an approach to reasoning about actions with sensing under qualitative and probabilistic uncertainty, while [34, 38, 37] explore game-theoretic extensions of probabilistic reasoning about actions. The works [13, 23, 57, 68] present probabilistic description logic programs, [24] investigates their application in ontology mapping, and [45] explores special cases. [47, 48, 66, 73] present fuzzy description logic programs, and [46, 74] propose a unified approach. Furthermore, [14, 69, 75] explore ontology-based ranking techniques, while [65] presents expressive probabilistic description logics. [44, 62, 63] present new approaches to description logic programs under the answer set semantics, and [6, 12, 67] deal with reasoning about imprecise probabilities.

Constraint-based architectures for planning and scheduling. This line of research synthesizes methods for solving planning and scheduling problems. A component-based proposal based on a uniform representation has been used in the OMPS architecture [60]. In ROBOCARE software and robotic agents are integrated to obtain complex functionalities in a domestic environment [58, 30, 16].

Computer vision and state estimation Computer Vision and State Estimation techniques are very important for monitoring an environment. An important task is detection and tracking of moving objects. The work [1] describes a real-time system based on stereo vision for tracking people from fixed cameras. This has been extended also with stereo cameras on mobile robots [28], and it has been adapted for boat traffic monitoring in the Grand Canal of Venice [21]. State estimation includes robot self-localization and simultaneous localization and mapping problems. State estimation for heterogeneous features has been studied in [50] using particle filters. Efficient optimizations for Rao-Blackwellized particle filters [8] have been developed to use less computational resources. In [51], an algorithm for marginal covariance computation in Graph-SLAM is presented. An integrated mapping technique fusing information from different sensors is described in [42].

Multi-robot and multi-agent systems Multi-Robot Systems (MRS) and Multi-Agent Systems (MAS) are a tool for implementing systems acting in complex environments. The research focussed on multi-objective multi-robot exploration, context domain design of robotics systems and coordination in a robots' team. The first topic is addressed in [27], analyzing some issues arising from rescue scenarios. In [5] we model exploration as a multi-objective problem, developing a prototype system, based on Petri Nets, which can adapt to different goals. As for the second activity, in [25, 26] we propose to characterize the contextual information in mobile robotic tasks as a design pattern, as such information can improve the performance of robots. Coordination in a robots' team is dealt in [53, 52], where we analyze the use of RFIDs to share knowledge. Finally, [55] provides two formal tools for modelling MAS, based on single-agent action languages and Petri nets.

Cognitive robotics, learning and perception Research activity on Cognitive Robotics is aimed at enhance cognitive skills of robotic platforms. Human eye movements have been studied by means of a patented device designed on purpose [76] and able to project user fixations in three dimension thanks to a novel calibration procedure. This has allowed to infer a plausible gaze behaviour to endow a robot with, as illustrated in [3]. An informal dissertation on human consciousness and its reproduction on robots was presented in [49]. Extensive works have been made in the context of autonomous robots working in rescue scenarios. In [29, 17] we presented

a task-oriented attentive exploration system where a visual-attention process guides the robot search using an incremental generation of a global saliency map. Learning based on interleaving of virtual and real experiments is presented in [32], while different layered methods for a soccer robotics task are shown in [31].

Constraint modelling and programming Declarative programming is becoming very attractive to solve different classes of problems, due to the fast prototyping and the high declarativeness exhibited by the problem models. Among the topics carried out, there's the automated reasoning on constraint declarative specifications [15]. We also investigate a class of problems called "Conditional Constraint Satisfaction Problems" (CCSP), supporting conditional activation of variables and constraints, characterizing the framework in terms of first-order logic. In [39] we analyze strategic games under incomplete information, investigating the complexity of the problem of deciding the existence of equilibria in pure strategies. Finally, we exploit constraint programming techniques for validating software engineering documentation, in particular UML class diagrams [22].

Computer graphics The Computer Graphics group focused on the research of novel physically-based animation methods. Such a task involves several design phases, from the mathematical modeling of the mechanical laws governing the motion of the real scene, to their discretization and numerical integration. The resulting virtual model of the scene can be used to synthesize realistic animation and for planning purposes.

During 2007, we developed a stable and robust method for real-time thread simulation [43] useful in developing 3D graphics applications, We also carried on the research on the automatic animation of virtual humans, in particular talking heads driven be facial gestures [33] or by cloning existing facial animation [7].

Journals

[1] Bahadori S., Iocchi L., Leone G. R., Nardi D., and Scozzafava L. Real-Time People Localization and Tracking through Fixed Stereo Vision *Applied Intelligence*, 26: 83–97, 2007.

[2] Balakirsky S., Carpin S., Kleiner A., Lewis M., Visser A., Wang J., and Ziparo V. A. Towards heterogeneous robot teams for disaster mitigation: Results and performance metrics from robocup rescue. *Journal of Field Robotics*, 24(11-12):943–967, November 2007.

[3] Belardinelli A., Carbone A., and Pirri F. Bottom-up gaze shifts and fixations learning, by imitation. In *IEEE Transactions on Systems, Man, and Cybernetics, Part B*, pp. 256–271, Vol 37, n.2, 2007.

[4] Cadoli M., Mancini T. Using a theorem prover for reasoning on constraint problems. *Applied Artificial Intelligence*, 21(4/5):383–404, 2007.

[5] Calisi D., Farinelli A., Iocchi L., and Nardi D. Multi-objective exploration and search for autonomous rescue robots. *Journal of Field Robotics, Special Issue on Quantitative Performance Evaluation of Robotic and Intelligent Systems*, 24:763–777, August - September 2007.

[6] Cano A., Cozman F. G., and Lukasiewicz T. Reasoning with imprecise probabilities. *International Journal of Approximate Reasoning*, 44(3):197–199, March 2007.

[7] Fratarcangeli M., Schaerf M., and Forchheimer R. Facial motion cloning with radial basis functions in mpeg-4 fba. *Graphical Models*, 69(2):106–118, March 2007.

[8] Grisetti G., Tipaldi G. D., Stachniss C., Burgard W., and Nardi D. Fast and Accurate SLAM with Rao-Blackwellized Particle Filters. *Robotics and Autonomous Systems, Special issue on Simultaneous Localization and Map Building*, 55(1): 30–38, 2007.

[9] Liberatore P. Consistency defaults. *Studia Logica*, 86(1):89–110, 2007.

[10] Liberatore P. Where fail-safe default logics fail. *ACM Transactions on Computational Logic*, 8(2), 2007.

[11] Liberatore P., Schaerf M. Compilability of propositional abduction. *ACM Transactions on Computational Logic*, 8(1):2, 2007.

[12] Lukasiewicz T. Nonmonotonic probabilistic logics under variable-strength inheritance with overriding: Complexity, algorithms, and implementation. *International Journal of Approximate Reasoning*, 44(3):301–321, March 2007.

[13] Lukasiewicz T. Probabilistic description logic programs. *International Journal of Approximate Reasoning*, 45(2):288–307, July 2007.

[14] Lukasiewicz T., Schellhase J. Variable-strength conditional preferences for ranking objects in ontologies. *Journal of Web Semantics*, 5(3):180–194, September 2007.

[15] Mancini T., Cadoli M. Exploiting functional dependencies in declarative problem specifications. *Artificial Intelligence* 171(16/17): 985–1010, 2007.

[16] Pecora F., Cesta A. DCOP for Smart Homes: a Case Study. *Computational Intelligence*, 23(4):395–419, 2007.

Articles in books

[17] Carbone A., Ciacelli D., Finzi A. and Pirri F. Autonomous Attentive Exploration in Search and Rescue Scenarios. In *Attention in Cognitive Systems*, pp. 431–446, Springer, LNCS, 2007.

Book

[18] Bobillo F., Da Costa P. G., D'Amato C., Fanizzi N., Fung F., Lukasiewicz T., Martin T., Nickles M., Peng Y., Pool M., Smrž P., and Vojtáš P. *Proceedings of the ISWC-2007 Workshop on Uncertainty Reasoning for the Semantic Web (URSW 2007)*, Busan, Korea, November 2007.

[19] Nardi D. *Proceedings of the IEEE International Workshop on Safety, Security and Rescue Robotics (SSRR 2007)*, Rome, Italy, September 2007. ISBN: 978-1-4244-1569-4, IEEE Catalog Number: CFP07SSR-PRT

Conference proceedings

[20] Bloisi D., Iocchi L. Image based Steganography and Cryptography. In *Proceedings of International Conference on Computer Vision Theory and Applications (VISAPP)*, 2007, pp. 127–134. ISBN: 978-972-8865-73-3.

[21] Bloisi D., Iocchi L., Leone G. R., Pigliacampo R., Tombolini L., and Novelli L. A Distributed Vision System for Boat Traffic Monitoring in the Venice Grand Canal. In *Proceedings of the International Conference on Computer Vision Theory and Applications (VISAPP)*, 2007, pp. 549–556. ISBN: 978-972-8865-74-0.

[22] Cadoli M., Calvanese D., De Giacomo G., and Mancini T.. Finite satisfiability of UML Class Diagrams by Constraint Programming. In *Proceedings of the Tenth Conference of the Italian Association for Artificial Intelligence (AI*IA 2007)*, Roma, Italy, 2007, pp. 36–47. Volume 4733 of *Lecture Notes in Computer Science*, Springer.

[23] Calì A. and Lukasiewicz T. Tightly integrated probabilistic description logic programs for the Semantic Web. In *Proceedings of the 23rd International Conference on Logic Programming (ICLP 2007)*, pp. 428–429, Porto, Portugal, September 2007. Volume 4670 of *Lecture Notes in Computer Science*, Springer, 2007.

[24] Calì A., Lukasiewicz T., Predoiu L., and Stuckenschmidt H. A Framework for representing ontology mappings under probabilities and inconsistency. In *Proceedings of the ISWC-2007 Workshop on Uncertainty Reasoning for the Semantic Web (URSW 2007)*, Busan, Korea, November 2007.

[25] Calisi D., Farinelli A., Grisetti G., Iocchi L., Nardi D., Pellegrini S., Tipaldi G. D., and Ziparo V. A. Contextualization in mobile robots. ICRA'07 Workshop on Semantic Information in Robotics, 2007.

[26] Calisi D., Farinelli A., Grisetti G., Iocchi L., Nardi D., Pellegrini S., Tipaldi G. D., and Ziparo V. A. Uses of contextual knowledge in mobile robots. In *Proceedings of the 10th Congress of the Italian Association for Artificial Intelligence (AI*IA 2007)*, pp. 543–554, 2007.

[27] Calisi D., Farinelli A., Iocchi L., and Nardi D.. Autonomous exploration for search and rescue robots. In *Proceedings of the International Conference on Safety and Security Engineering (SAFE)*, pp. 305–314, 2007. ISBN:978-1-84564-068-2.

[28] Calisi D., Iocchi L., and Leone R.. Person Following through Appearance Models and Stereo Vision using a Mobile Robot. In *Proceedings of International Workshop on Robot Vision*, 2007, pp. 46–56. ISBN: 978-972-8865-76-4.

[29] Carbone A., Ciacelli D., Finzi A., and Pirri F. Autonomous Attentive Exploration in Search and Rescue Scenarios. In *Proceedings of 4th International Workshop on Attention in Cognitive Systems*, 2007.

[30] Cesta A., Cortellessa G., Pecora F., and Rasconi R. Synthesizing Proactive Assistance with Heterogeneous Agents. *AI*IA 2007*, pp 495–506, 2007.

[31] Cherubini A., Giannone F., and Iocchi L. Layered Learning for a soccer legged robot helped with a 3D simulator. In *Proceedings of RoboCup International Symposium (CDROM Proceedings)*, 2007.

[32] Cherubini A., Giannone F., Iocchi L., and Palamara P. F. An extended policy gradient algorithm for robot task learning. In *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2007.

[33] Fanelli G., Fratarcangeli M. A non-invasive approach for driving virtual talking heads from real facial movements. In *IEEE 3DTV Conference*, Kos Island, Greece, May, 2007. IEEE.

[34] Farinelli A., Finzi A., and Lukasiewicz T. Team programming in Golog under partial observability. In *Proceedings of the 20th International Joint Conference on Artificial Intelligence (IJCAI 2007)*, pp. 2097–2102, Hyderabad, India, January 2007. IJCAI/AAAI Press, 2007.

[35] Farinelli A., Scerri P., Ingenito A., and Nardi D. Dealing with Perception Errors in Multi-Robot System Coordination In *Proceedings of the Joint International Conference on Artificial Intelligence (IJCAI-07)*, Hyderabad, India, pp 2091–2096, 2007.

[36] Ferrara A., Liberatore P., and Schaerf M. Model checking and preprocessing. In *Lecture Notes in Computer Science: Artificial Intelligence and Human-Oriented Computing*, volume 4733, pp. 48–59. Springer, 2007.

[37] Finzi A., Lukasiewicz T. Adaptive multi-agent programming in GTGolog. In *Proceedings of the 29th Annual German Conference on Artificial Intelligence (KI 2006)*, pp. 389–403, Bremen, Germany, June 2006. Volume 4314 of *Lecture Notes in Computer Science*, Springer, 2007.

[38] Finzi A., Lukasiewicz T. Game-theoretic agent programming in Golog under partial observability. In *Proceedings of the 29th Annual German Conference on Artificial Intelligence (KI 2006)*, pp. 113–127, Bremen, Germany, June 2006. Volume 4314 of *Lecture Notes in Computer Science*, Springer, 2007.

[39] Gottlob G., Greco G., and Mancini T. Complexity of pure equilibria in bayesian games. In *Proceedings of the Twentieth International Joint Conference on Artificial Intelligence (IJCAI 2007)*, Hyderabad, India, 2007, pp. 1294–1299. Morgan Kaufmann, Los Altos.

[40] Gottlob G., Greco G., and Mancini T. Conditional constraint satisfaction: Logical foundations and complexity. In *Proceedings of the Twentieth International Joint Conference on Artificial Intelligence (IJCAI 2007)*, Hyderabad, India, 2007, pp. 88–93. Morgan Kaufmann, Los Altos.

[41] Iocchi L., Dalla Libera F., and Menegatti E. Learning Biped Locomotion using Interleaved Simulated and Real Data. In *Proceedings of 2nd Workshop on Humanoid Soccer Robots*, 2007. ISBN:978-88-95872-00-1.

[42] Iocchi L., Pellegrini S., and Tipaldi G. D. Building multi-level planar maps integrating LRF, stereo vision and IMU sensors. In *Proceedings of IEEE International Workshop on Safety, Security and Rescue Robotics (SSRR)*, 2007.

[43] Kubiak B., Pietroni N., Ganovelli F., and Fratarcangeli M. A robust method for real-time thread simulation. In *VRST '07: Proceedings of the 2007 ACM symposium on Virtual reality software and technology*, pp. 85–88, New York, NY, USA, 2007. ACM.

[44] Lukasiewicz T. A novel combination of answer set programming with description logics for the Semantic Web. In *Proceedings of the 4th European Semantic Web Conference (ESWC 2007)*, pp. 384–398, Innsbruck, Austria, June 2007. Volume 4519 of *Lecture Notes in Computer Science*, Springer, 2007.

[45] Lukasiewicz T. Tractable probabilistic description logic programs. In *Proceedings of the 1st International Conference on Scalable Uncertainty Management (SUM 2007)*, pp. 143–156, Washington DC, USA, October 2007. Volume 4772 of *Lecture Notes in Computer Science*, Springer, 2007.

[46] Lukasiewicz T., Straccia U. Description logic programs under probabilistic uncertainty and fuzzy vagueness. In *Proceedings of the 9th European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty (ECSQARU 2007)*, pp. 187–198, Hammamet, Tunisia, October/November 2007. Volume 4724 of *Lecture Notes in Computer Science*, Springer, 2007.

[47] Lukasiewicz T., Straccia U. Tightly integrated fuzzy description logic programs under the answer set semantics for the Semantic Web. In *Proceedings of the 1st International Conference on Web Reasoning and Rule Systems (RR 2007)*, pp. 289–298, Innsbruck, Austria, June 2007. Volume 4524 of *Lecture Notes in Computer Science*, Springer, 2007.

[48] Lukasiewicz T., Straccia U. Top-k retrieval in description logic programs under vagueness for the Semantic Web. In *Proceedings of the 1st International Conference on Scalable Uncertainty Management (SUM 2007)*, pp. 16–30, Washington DC, USA, October 2007. Volume 4772 of *Lecture Notes in Computer Science*, Springer, 2007.

[49] Pirri F. The Prince of Holmberg. In *Proceedings on Consciousness and Artificial Intelligence: Theoretical foundations and current approaches*, 2007.

[50] Tipaldi G. D., Farinelli A., Iocchi L., and Nardi D. Heterogeneous Feature State Estimation with Rao-Blackwellized Particle Filters. In *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*, 2007, pp. 3850–3855.

[51] Tipaldi G. D., Grisetti G., and Burgard W. Approximated Covariance Estimation in Graphical Approaches to SLAM. In *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2007.

[52] Ziparo V. A., Kleiner A., Marchetti L., Farinelli A., and Nardi D. Cooperative exploration for USAR robots with indirect communication. In *Proceedings of 6th IFAC Symposium on Intelligent Autonomous Vehicles (IAV '07)*, 2007.

[53] Ziparo V. A., Kleiner A., Nebel B., and Nardi D. Rfid-based exploration for large robot teams. In *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, Rome, Italy, 2007. ISBN:1-4244-0602-1, ISSN:1050-4729.

Ph.D. thesis

[54] Pecora F. *Multi-Agent Planning and Coordination Under Resource Constraints*. PhD thesis, Dipartimento di Informatica e Sistemistica Antonio Ruberti, Sapienza Università di Roma, 2007.

[55] Ziparo V. A. *Robot Teams for Multi-Objective Tasks*. PhD thesis, Dipartimento di Informatica e Sistemistica Antonio Ruberti, Sapienza Università di Roma, 2007.

Submitted papers, technical reports and others

[56] Benedetti M., Pecora F., and Policella N. Anatomy of a Scheduling Competition. In *SSC-07, ICAPS Workshop on Scheduling a Scheduling Competition, Providence, RI, USA*, 2007.

[57] Calì A., Lukasiewicz T. Tightly integrated probabilistic description logic programs. Technical Report Nr. 1843-07-05, Institut für Informationssysteme, Technische Universität Wien, March 2007.

[58] Cesta A., Cortellessa G., Pecora F., and Rasconi R. Coordinating Heterogeneous Agents to Synthesize Proactive Monitoring. *ICAPS Workshop on Planning and Plan Execution for Real-World Systems*, Providence, RI, USA, 2007.

[59] Cesta A., Cortellessa G., Pecora F., and Rasconi R. Supporting Interaction in the ROBOCARE Intelligent Assistive Environment. In *Proceedings of AAAI Spring Symposium on Interaction Challenges for Intelligent Assistants*, 2007.

[60] Cesta A., Fratini S., and Pecora F. A Multi-Component Framework for Planning and Scheduling Integration. In *Proceedings of the 26th Workshop of the UK Planning and Scheduling Special Interest Group* (PlanSIG-07), Prague, Czech Republic, 2007.

[61] Da Costa P. C. G., Laskey K. B., and Lukasiewicz T. Uncertainty representation and reasoning in the Semantic Web. In *Semantic Web Engineering in the Knowledge Society*, in press.

[62] Eiter T., Ianni G., Lukasiewicz T., Schindlauer R., and Tompits H. Combining answer set programming with description logics for the Semantic Web. Technical Report Nr. 1843-07-04, Institut für Informationssysteme, Technische Universität Wien, March 2007.

[63] Eiter T., Ianni G., Lukasiewicz T., Schindlauer R., and Tompits H. Combining answer set programming with description logics for the Semantic Web. *Artificial Intelligence*, in press.

[64] Iocchi L., Lukasiewicz T., Nardi D., and Rosati R. Reasoning about actions with sensing under qualitative and probabilistic uncertainty. *ACM Transactions on Computational Logic (TOCL)*, in press.

[65] Lukasiewicz T. Expressive probabilistic description logics. *Artificial Intelligence*, 172(6-7):852–883, April 2008.

[66] Lukasiewicz T. Fuzzy description logic programs under the answer set semantics for the Semantic Web. *Fundamenta Informaticae*, 82(3):289–310, 2008.

[67] Lukasiewicz T. Logical approaches to imprecise probabilities. *International Journal of Approximate Reasoning*, in press.

[68] Lukasiewicz T. Probabilistic description logic programs under inheritance with overriding for the Semantic Web. *International Journal of Approximate Reasoning*, in press.

[69] Lukasiewicz T., Schellhase J. Variable-strength conditional preferences for ranking objects in ontologies. Technical Report Nr. 1843-07-06, Institut für Informationssysteme, Technische Universität Wien, April 2007.

[70] Lukasiewicz T. Straccia U. Managing uncertainty and vagueness in description logics for the Semantic Web. Accepted for publication in *Journal of Web Semantics*.

[71] Lukasiewicz T., Straccia U. Managing uncertainty and vagueness in semantic web languages. Tutorial at the *4th European Semantic Web Conference (ESWC 2007)*, Innsbruck, Austria, June 2007.

[72] Lukasiewicz T., Straccia U. Managing uncertainty and vagueness in semantic web languages. Tutorial at the *22nd National Conference on Artificial Intelligence (AAAI 2007)*, Vancouver, British Columbia, Canada, July 2007.

[73] Lukasiewicz T., Straccia U. Tightly integrated fuzzy description logic programs under the answer set semantics for the Semantic Web. Technical Report Nr. 1843-07-03, Institut für Informationssysteme, Technische Universität Wien, February 2007.

[74] Lukasiewicz T., Straccia U. Uncertainty and vagueness in description logic programs for the Semantic Web. Technical Report Nr. 1843-07-02, Institut für Informationssysteme, Technische Universität Wien, February 2007.

[75] Schellhase J., Lukasiewicz T. Using search strategies and a description logic paradigm with conditional preferences for literature search. *International Journal of Metadata, Semantics and Ontologies*, in press.

Patents

[76] Pirri F., Belardinelli A., and Carbone A. Patent number RM2007A000526: Gaze Machine. Copyright *Sapienza*, 2007.

3.1.3 Communication Networks

The research activity of the group of Communication Networks (CN) is concerned with the design, the theoretical and experimental performance analysis of protocols for problems arising in modern Computer Systems and Networks. The performed activities are in close connections with the activity performed in Algorithm Engineering and Distributed Systems.

Faculty members Roberto BALDONI, Luca BECCHETTI, Roberto BERALDI, Stefano LEONARDI, Alberto MARCHETTI-SPACCAMELA, Andrea VITALETTI.
PhD students Adnan NOOR MIAN,Ugo COLESANTI.

The CN group is currently cooperating with several prestigious research institutions: CTI-Patras and University of Athens (Greece), ETH (Zurich, Switzerland), Yahoo Research Barcelona (Spain) INRIA (France), UPM (Spain), LAAS (Toulouse, France), Technion (Haifa, Israel), Univ. of Rennes (France), INRIA (France).

The group has a research contract with E.U projects AEOLUS, FRONTS and GRAAL and a FIRB project Italy/Israel with Technion, Haifa.

The CN group is presently involved in the following research projects: ALENIA Spazio "Wideband Wireless Local Area Network" (WWLAN); EU Contract 001907 "Dynamically Evolving Large Scale Information Sytems" (DELIS); EU/IST Integrated Project IP-FP6-015964 AEOLUS, "Algorithmic Principles for Building Efficient Overlay Computers"; MIUR National Project "Algorithms for the Next Generation Internet and Web: Methodologies, Design and Application" (ALGO-NEXT); MIUR Firb international Italian-Israelian cooperation RBIN047MH9 project; "Resilience for Survivability in IST" ReSIST (EU-IST); MIUR's project "Infrastrutture Software per Reti Ad-hoc Orientate ad Ambienti Difficili" (IS-MANET).

As far as the research areas are concerned, the NC group focus on the following main topics

- Ad hoc wireless networks
- Sensor networks

Ad Hoc wireless networks In [6] we presented a novel probabilistic protocol for path discovery in Mobile Ad Hoc Networks (MANETs). The protocol implements the so-called *polarized gossiping* algorithm. *Random walks* can also be exploited for addressing searching problems. The work described in [3] shows how random walks can be used for service discovery, while the work in [8] considers walks on uniform wireless networks and studies how to reduce the expected number of walk steps required to reach a given target, namely the hitting time. Additional results concerning random walks can be found in [7], where we have studied the case when a random walk can make long jumps and in [10], where an energy efficient implementation is proposed.

Sensor networks In [9] the problem of efficient data gathering in a wireless network through multi-hop communication is considered focusing on the objective of minimizing the maximum flow time of a data packet. In [1] we tackle the problem of designing simple, localized, low energy consuming, reliable protocols for one-to-all communication in large scale wireless sensor networks. In [5] we present a framework for passive inspection of deployed sensor networks and show how this framework can be used to inspect data gathering applications. In [4] we study the data aggregation problem as a bicriteria optimization problem. Finally, we present an implementation of Rijndael for wireless sensor networks running on Eyes sensor nodes in [2].

Journals

[1] Dubashi D., Häggström O., Orecchia L., Panconesi A., Petrioli C. and Vitaletti A. Localized techniques for broadcasting in wireless sensor networks *Algoritmica*, Vol. 49, 4, pp 412-446, 2007.

[2] Vitaletti A. and Palombizio G. Rijndael for Sensor Networks: Is Speed the Main Issue? *Electronic Notes in Theoretical Computer Science*, Vol.171, 1,

Conference proceedings

[3] Beraldi R., Service discovery in MANET via biased random walks, *Autonomics 2007*, Rome, Italy

[4] Korteweg P., Marchetti-Spaccamela A., Stougie L., Vitaletti A. Data Aggregation in Sensor Networks: Balancing Communication and Delay Cost, *SIROCCO07*, Castiglioncello (LI), Italy

[5] Ringwald M. , Römer K. and Vitaletti A. Passive Inspection of Sensor Networks, *DCOSS 2007*, Santa Fe, New Mexico, USA

Submitted papers, technical reports and others

[6] Beraldi R., The Polarized Gossip Protocol for Path Discovery in MANETs. *Elsevier Ad Hoc Networks* (January 2008).

[7] Beraldi R., Random walk with long jumps for wireless ad hoc networks *Elsevier Ad Hoc Networks* (accepted for publication).

[8] Beraldi R., Querzoni L., Baldoni R., Low hitting time random walks in wireless networks. In *Wireless Communications and Mobile Computing* (accepted for publication).

[9] Bonifaci V., Korteweg P. and Marchetti-Spaccamela A. Minimizing Flow Time in the Wireless Gathering Problem. In *STACS 2008*.

[10] Noor Mian A., Beraldi R., Baldoni R. A Robust and Energy Efficient Protocol for RandomWalk in Ad hoc Networks with IEEE 802.11. In *PMEO-IPDPS 2008*.

3.1.4 Data and Knowledge Bases

The research activities of the group working on Data and Knowledge Bases are mainly oriented towards the following topics:

- Description Logics, i.e., the specification of formal languages for representing structured knowledge in different contexts, and for reasoning over such knowledge with suitable computational properties.
- Information Integration, with special focus on data integration and exchange under integrity constraints, data inconsistency, and ontology-based information integration.
- Semantic Web and Ontologies, i.e., design and development of Ontology-based Information Systems for knowledge representation, reasoning, and data access in the Semantic Web.
- View-based Query Processing, and in particular view-based query answering, rewriting and containment.
- Information Visualization, with special focus on theoretical and application-oriented aspects of visual formalisms for data-bases and database design, on Visual Query Languages and Interfaces, Visual Data Mining, and clutter reduction.
- Mobile Information Access, with particular interest on designing applications for multiple user interfaces, and studying the impact of technologies, especially mobile, on digital libraries.
- User interfaces to digital libraries, i.e., the study of user interface design and information visualization in digital libraries.

- E-learning, and in particular the study of how to make accessible information contents.
- Data Quality, with focus on both defining and measuring the quality of data and on the issue of improving the quality of data through data cleaning techniques, specifically record linkage and object identification techniques.

The group is presently involved in several research projects, including the following: EU Project IST-508011 "INTEROP"; EU Project FP6-2005-IST-5-034749 "WORKPAD"; MIUR (PRIN) project "ESTEEM"; Progetto CNR "VICE"; IST NoE "DELOS" (G038-507 618); EU project IFP7-ICT-2007-C-FET-Open "VISMASTER CA"; project HYPER, funded by IBM through a Shared University Research (SUR) Award grant; MIUR FIRB 2005 project "TOCAI.IT" (Tecnologie Orientate alla Conoscenza per Aggregazioni di Imprese in Internet); EU FET project FP6-7603 "TONES" (Thinking ONtologiES).

Group members are:

Faculty members: Tiziana CATARCI, Giuseppe DE GIACOMO, Domenico LEMBO, Maurizio LENZERINI, Riccardo ROSATI, Silvio SALZA, Giuseppe SANTUCCI
Post-Docs: Antonella POGGI, Marco RUZZI, Enrico BERTINI
PhD students: Sha Rukh HUMAYOUN, Luigi DRAGONE
Visitors: Carola AIELLO, Monica SCANNAPIECO

Research activity is described in the following, by grouping works and contributions of the group for each of the above mentioned topics.

Description logics. The goal of the research in Description Logics (DLs) is to study the foundations of class-based knowledge representation formalisms. In [4], a foundational study, comprising intensional reasoning and conjunctive query answering, is provided on a family of DLs, called DL-Lite, rich enough to express the fundamental constructs of class-based formalisms, but keeping tractable reasoning in the size of the data. Answering expressive queries over knowledge bases (KBs) expressed in DL-Lite, as well as specified in other DL languages, is considered in [14], whereas the problem of updating DL-Lite KBs at the instance level is addressed in [17, 33], and the problem of dealing with data inconsistency is dealt with in [23]. Also, an extension of DL-Lite allowing for the specification of identification constraints is given in [13]. Finally, conjunctive query containment under DL constraints is studied in [29], conjunctive query answering in the tractable Description Logic EL is dealt with in [26], and the relationship between DLs and logic programming is addressed in [24].

Information Integration. The Data and Knowledge Bases research group has addressed several among the most important problems that arise in information integration, both from a theoretical and a practical point of view. In [11] a tool is presented, called MASTRO-I, for data integration in the presence of a global unified view expressed in terms of an ontology. Then, following the line of research on integration of possibly inconsistent data, carried out in the last years by group members, in [34] query answering over inconsistent data is studied in the simplified setting of relational databases, and optimization issues, well-suited for data integration, are presented. Research on information integration, including issues above, as well as data exchange, peer-to-peer data management, and service composition is addressed in the context of the activity of the DASI-lab (http://www.dis.uniroma1.it/∼dasilab/).

Semantic Web and Ontologies. The Semantic Web (SW) is a Web in which the semantics of information and services is defined, making it possible to represent and exchange data and knowledge over the Web in a machine processable form. Description Logics (DLs) are nowadays playing a central role in the Semantic Web, since they are currently the most used formalisms for building ontologies, whose use is at the basis of the SW. Moving from the extensive work carried out in the field of DLs (see above), the group considered important issues arising in the area of SW and ontology representation and reasoning. More specifically, In [35, 12] extensions of DL-Lite (see above) are considered for SW applications, which allows us to profitably link databases to DL-Lite ontologies, in order to access data in the semantic web. In [32], a preliminary report is given on DL-Lite extensions for representing and reasoning about meta-level elements. Finally, decidability of answering expressive queries over DL otologies is considered in [25], and actions and programs over DL ontologies is addressed in [15].

View-based query processing. View-based query processing is the problem of processing a query posed to a database only on the basis of the information on a set of views, which are again queries over the same database. Several papers in the literature show that the problem is relevant in many aspects of database management, including query optimization, data warehousing, data integration, and query answering with incomplete information. In the last year, our research has been mainly focused on the study of the fundamental notions in view-based query processing of rewriting, answering and losslessness, and of the relationship between them. In [5] several of such notions are compared and relationships between them are analyzed.

Information visualization. Information Visualization is the use of computer-based, visual, interactive representations of information, with the purpose of making sense of data, acquire knowledge, discover new information, and present the result effectively. In the last year 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 domine taking into account its frequency distributions, as described in [10]. Our analysis pointed out that conventional linear mappings perform very poorly and some distortions are useful to produce better images. Moreover we continued to work on evaluation problems and in [3] we reported the issues outcoming from the BELIV'06 ("BEyond time and errors: novel evaLuation methods for Information Visualization") workshop, organized in the context of the AVI 2006 conference. The workshop's results were very interesting and we organized a second edition that has been hosted by the ACM CHI'08 conference.

Mobile information access. Mobile computing is a major innovation of our Days. The wide spread of mobile devices, applications and connected services permits to access information anytime anywhere and to bring along personal information while staying mobile [1]. In this context the design of adaptive interfaces is a key element for the success of software and devices since very often the same application is accessed by different portable devices characterized by different capabilities and interaction modalities [31]. In the last year we focused on a UML based environment that allows for designing in abstract way an application that is automatically adapted to different physical devices. In [2] we present the main issues of this approach, together with a methodology to asses and control the overall application quality. Moreover, In the last year we focused our activity on the design and testing of a complete usability evaluation methodology for mobile devices presented in [9] and [7].

User interfaces to digital libraries. In this area, we have been involved in user interface design and information visualization in digital libraries (DLs). In the last year we focused on

non-standard data searching. In such a case, automatically derived meta-data are typically used. In [22], we address benchmarking of meta data schemas and support to user queries in a two-fold contribution. Based on the DARE visualization system, we first introduce an approach for the *visual benchmarking* of multiple meta data formats on a ground truth benchmark, supporting the optimization stage of the multimedia database design. We secondly propose a simple, yet effective *visual interface* to multiple, long lists (rankings) of answer objects for the user. Moreover, the research activity continued to investigate novel techniques for DL, navigation such as advanced browsing by catalogues, scatter browsing, and semantic linking, presented in [19], [20], [21], and [18]. Finally, Besides investigating non-conventional paradigms, we have been working on Task-centered Information Management in digital libraries. In the process, we have proposed a language to model desktop users' activities that are performed most frequently [16] and designed an architecture for the overall system implementing it [8].

E-learning. As far as e-learning is concerned, we have mainly focused on accessibility. In the process, we have managed to realize an approach for creating/authoring accessible e-learning content and resources [30]. The approach is based on simplicity, doing away with what is not necessary in order to give room to/include what is necessary. The approach comprises accessibility guidelines which are intended to be referred to/used during the process of creating accessible e-learning content. The guidelines that we have proposed are based on an association between disabilities and critical content types. Our work on the approach also includes an environment for supporting didactical and pedagogical experts during the process of developing accessible e-learning artifacts.

Data quality and data cleaning. Record linkage is among the most important data quality activities. We are investigating the relationships between record linkage and privacy. Specifically, in [27] we have studied how to perform record linkage in a privacy preserving way. Indeed, nodes joining a networked system are willing to share information with other nodes. If such information need to be privacy protected, any record linkage process should be aware of privacy requirements and properly address them. We are also studying how to automatically build record linkage workflows by taking into account specific data and application requirements. In [28], we have formalized the problem and proposed some methods for the its solution. Besides record linkage, a further research issue is related to the management of data quality issues in complex systems like networked ones. In [6], a distributed architecture implementing methods for evaluating, accessing and improving quality of data in a peer-to-peer system is described.

Journals

[1] Atzeni P., Catarci T., and Pernici B. Multi-channel adaptive information systems. *World Wide Web*, 10(4):345–347, 2007.

[2] Batini C., Bertini E., Comerio M., Maurino A., Santucci G., Visual languages and quality evaluation in multichannel adaptive information systems. *Journal of Visual Languages and Computing*, 18.5:513–522, 2007.

[3] Bertini E., Plaisant C., and Santucci G., BELIV'06: Beyond time and errors; novel evaluation methods for information visualization. *Interactions*, XIV.3:59–60, 2007.

[4] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., and Rosati R. Tractable reasoning and efficient query answering in description logics: The DL-Lite family. *Journal of Automated Reasoning*, 39(3):385–429, 2007.

[5] Calvanese D., De Giacomo G., Lenzerini M., and M. Y. Vardi. View-based query processing: On the relationship between rewriting, answering and losslessness. *Theoretical Computer Science*, 371(3):169-182, 2007.

[6] Milano D., Scannapieco M., and Catarci T., Measuring and Diffusing Data Quality in a Peer-to-Peer Architecture, *International Journal of Enterprise Information Systems*, 3(1), 2007.

Articles in books

[7] Bertini E., Catarci T., Dix A., Gabrielli S., Kimani S., and Santucci G. *Handbook of Research on User Interface Design and Evaluation for Mobile Technology*, chapter Appropriating Heuristic Evaluation Method for Mobile Computing. Idea Group Inc., GBR, 2007.

[8] Catarci T., Dong D., Halevy A., and Poggi A.. *Personal Information Management*, chapter Structure Everything, pages 108–126. University of Washington Press, USA, 2007.

Conference proceedings

[9] Burzagli L., Billi M., Palchetti E., Catarci T., Santucci G., and Bertini E. Accessibility and usability evaluation of mais designer: A new design tool for mobile services. In *HCI (6)*, pages 275–284, 2007.

[10] Bertini E., Di Girolamo A., and Santucci G, See what you know: analyzing data distribution to improve density map visualization. In *Proc. of the Int. Eurovis 2007 conference*, 2007.

[11] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., Poggi A., and Rosati R. MASTRO-I: Efficient integration of relational data through dl ontologies. In *Proc. of the 2007 Description Logic Workshop (DL 2007)*, volume 250 of *CEUR Electronic Workshop Proceedings, http://ceur-ws.org/Vol-250/*, pages 227–234, 2007.

[12] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., Poggi A., and Rosati R. Ontology-based database access. In *Proc. of the 15th Italian Conf. on Database Systems (SEBD 2007)*, pages 324–331, 2007.

[13] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., and Rosati R. Can owl model football leagues? In *Proc. of the 3rd Workshop on OWL: Experiences and Directions (OWLED 2007)*, volume 258 of *CEUR Electronic Workshop Proceedings, http://ceur-ws.org/Vol-258/*, 2007.

[14] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., and Rosati R. EQL-Lite: Effective first-order query processing in description logics. In *Proc. of the 20th Int. Joint Conference on Artificial Intelligence (IJCAI 2007)*, pages 274–279, 2007.

[15] Calvanese D., De Giacomo G., Lenzerini M., and Rosati R. Actions and programs over description logic ontologies. In *Proc. of the 2007 Description Logic Workshop (DL 2007)*, volume 250 of *CEUR Electronic Workshop Proceedings, http://ceur-ws.org/Vol-250/*, pages 29–40, 2007.

[16] Catarci T., Dix A. J., Katifori A., Lepouras G., and Poggi A. Task-centred information management. In *DELOS Conference*, pages 197–206, 2007.

[17] De Giacomo G., Lenzerini M., Poggi A., and Rosati R. On the Approximation of Instance Level Update and Erasure in Description Logics. In *Proc. of the 22nd Conference on Artificial Intelligence (AAAI 2007)*, pages 403–408, 2007.

[18] Dubinsky Y., Catarci T., Bertini E., and Kimani S. Catalogue browsing interaction and access to library resources. In *Proc. of the PersDL Workshop*, 2007.

[19] Dubinsky Y., Catarci T., and Kimani S. The catalogue browsing access paradigm. In *IRCDL*, pages 38–45, 2007.

[20] Dubinsky Y., Catarci T., and Kimani S. A user-based method for speech interface development. In C. Stephanidis, editor, *HCI (5)*, volume 4554 of *Lecture Notes in Computer Science*, pages 355–364. Springer, 2007.

[21] Dubinsky Y., Catarci T., and Kimani S. Using catalogue browsing for speech-based interface to a digital library. In *Proc. of the 2nd IASTED Int. Conference on Human-Computer Interaction(IASTED-HCI)*, 2007.

[22] Iervella G., Iannarelli S., Veltri F., Catarci T., Keim D., Santucci G., and Schreck T., Visual rank analysis for search engine benchmarking and efficient navigation. In *Proc. of the 2nd Int. Delos conference on digital libraries*, 2007.

[23] Lembo D. and Ruzzi M. Consistent query answering over description logic ontologies. In *Proc. of the 1st Int. Conf. on Web Reasoning and Rule Systems (RR 2007)*, 2007.

[24] Motik B. and Rosati R. A faithful integration of description logics with logic programming. In *Proc. of the 20th Int. Joint Conference on Artificial Intelligence (IJCAI 2007)*, 2007.

[25] Rosati R. The limits of querying ontologies. In *Proc. of the 11th Int. Conference on Database Theory (ICDT 2007)*, volume 4353 of *Lecture Notes in Computer Science*, pages 164–178. Springer, 2007.

[26] Rosati R. On conjunctive query answering in el. In *Proc. of the 2007 Description Logic Workshop (DL 2007)*, volume 250 of *CEUR Electronic Workshop Proceedings, http://ceur-ws.org/Vol-250/*, 2007.

[27] Scannapieco M., Figotin I., Bertino E. and Elmagarmid A.K., *Privacy Preserving Schema and Data Matching*, Proc. of the 27th ACM SIGMOD Conference (SIGMOD 2007), 2007.

[28] Tuoto T., Cibella N., Fortini M., Scannapieco M., and Tosco T., *RELAIS: Don't Get Lost in a Record Linkage Project*, Proc. of the Federal Committee on Statistical Methodologies (FCSM 2007) Research Conference, 2007 .

Submitted papers, technical reports and others

[29] Calvanese D., De Giacomo G., and Lenzerini M. Conjunctive query containment and answering under description logic constraints. *ACM Trans. on Computational Logic*, 9(3), 2008. In Press.

[30] Catarci T., de Giovanni L., Gabrielli L., Kimani S., and Mirabella V. Scaffolding the design of accessible elearning content: A user-centred approach and cognitive perspective. *Cognitive Processing*, 2008. In press.

[31] Catarci T., Dix A., Gabrielli S., and Kimani S. *Advances in Ubiquitous Computing: Future Paradigms and Directions*, chapter Designing for Tasks in Ubiquitous Computing: Challenges and Considerations. IGI Publishing, GBR. In press.

[32] De Giacomo G., Lenzerini M., and Rosati R. Towards higher-order dl-lite. In *Proc. of the 2008 Int. Workshop on Description Logic (DL 2008)*, 2008. To Appear.

[33] De Giacomo G., Lenzerini M., Poggi A., and Rosati R. On instance-level update and erasure of description logic ontologies. *Journal of Logic and Computation*, 2008. In Press.

[34] Eiter T., Fink M., Greco G., and Lembo D. Repair localization for query answering from inconsistent databases. *ACM Transactions on Database Systems*, 2008. In Press.

[35] Poggi A., Lembo D., Calvanese D., De Giacomo G., Lenzerini M., and Rosati R. Linking data to ontologies. *Journal on Data Semantics*, X:133–173, 2008.

3.1.5 Distributed Software Architectures for Data and Services

The Distributed Software Architectures for Data and Services is an interdisciplinary area merging the competencies of some members of the Data and Knowledge Bases group and of the Distributed Systems group, with the aim of providing leading-edge research both at the infrastructure and application layer.

The topics addressed are both theoretical and application-oriented, in the fields of:

- Service Oriented Computing, with specific focus on Service Composition, Adaptive Computing and Cooperative Applications in Specific Scenarios.
- Peer-to-Peer Computing, with specific focus on Peer-to-Peer Data Management.

The area comprises several projects, including the following: Progetto MIUR (FIRB 2003) eG4M - eGovernment for Mediterranean Countries; Progetto MIUR (FIRB 2005) TOCAI.IT - Tecnologie Orientate alla Conoscenza per Aggregazioni di Imprese in Internet; Progetto IST "TONES"; Progetto IST "SemanticGOV"; Progetto IST "WORKPAD".
The members of the joint area are:

Faculty members: Roberto BALDONI, Tiziana CATARCI, Giuseppe DE GIACOMO, Domenico LEMBO, Maurizio LENZERINI, Massimo MECELLA
Post-Docs: Antonella POGGI, Leonardo QUERZONI
PhD students: Silvia BONOMI, Massimiliano DE LEONI, Luigi DRAGONE, Fabio PATRIZI
Visitors: Claudio DI CICCIO, Pierandrea FEDERICI, Andrea MARRELLA, Damiano POZZI, Ruggero RUSSO, Tommaso SANGUIGNI

Research activity is described in the following, by grouping works and contributions of the area for each of the above mentioned topics.

Service Composition. Services (also called *e*-Services or Web Services) are autonomous platform-independent computational elements that can be described, published, discovered, orchestrated and programmed for the purpose of developing distributed interoperable applications.

Our research has been particularly focused on automatic service composition. Service composition addresses the situation when a client request cannot be satisfied by any available service, but a composite service, obtained by combining "parts of" available component services, might be used. Results have been presented in [5, 7, 8, 13, 15, 18]. Our techniques are recognized at international level among the first ones which have been proved to be correct wrt the semantics. In particular members of the group delivered an invited course on automatic service composition at the INFWEST EU-funded Seminar School (June 5 – 7, 2008 – cfr. `http://www.jyu.fi/it/laitokset/cs/en/infwest/seminars/webservices`).

Adaptive Computing. The adaptive computing research activity is devoted to study and analyze adaptive aspects of cooperative information systems in highly mobile contexts, such as the ones of Mobile Ad hoc NETworks (MANETs), i.e., networks of mobile devices (PDAs, smartphones, laptops) which communicate each other across wireless channels (802.11x, Bluetooth), without a wired backbone infrastructure, and in a peer-to-peer fashion. The most important peculiarities of these systems are the strict collaboration among mobile devices and actors constituting the network.

The main goals are to investigate and define techniques, models, methods, and algorithms for supporting dynamic changes and adaptivity in process management as well as the design and

development of a platform able to provide a communication software level and to support the development of distributed applications for MANET contexts. Results have been presented in [4, 10, 11, 12, 17].

Cooperative Applications in Specific Scenarios. The paradigm of the Service Oriented Computing (SOC) can be effectively applied in designing and deploying Cooperative Information Systems, i.e., systems in which multiple organizations integrate data and application services across heterogeneous networks in order to achieve common goals and processes.

Specifically, in [2, 14] a SOA-based architecture is proposed for the Italian Cooperative Information System (SPCoop), jointly with the Italian CNIPA, dealing in particular with orchestration and QoS issues.

Moreover, the topic of adaptive computing is specifically tailored for designing and developing innovative software infrastructures for supporting collaborative work of human operators in emergency/disaster scenarios [3, 9].

Peer-to-Peer Data Management and Interoperability. In (data intensive) peer-to-peer systems, each peer is an autonomous system that exports data in terms of its own data schema, and imports data from other peers to which it is connected through suitable mappings. In [16], a novel specific formalization based on multi-modal epistemic logic is proposed, where the idea is that each peer is a rational agent that exchanges knowledge with other peers. In the same paper, also the issue of data inconsistency is considered, and a nonmonotonic extension of the logic is proposed that is able to repair mutual inconsistent information flowing from different peers. A recent development on peer-to-peer data management combining together data integration and data exchange (the latter being the problem of physically moving the data from one peer to another, and hence is concerned with materialization issues) has been presented in [6]. Finally, in [1] a family of nonmonotonic multimodal logics is studied, which is suited for modeling information in peer data management systems.

Journals

[1] Rosati R. Multi-modal Nonmonotonic Logics of Minimal Knowledge. *Annals of Mathematics and Artificial intelligence*, 48 (3-4):169–185, 2007.

Conference proceedings

[2] Baldoni R., Fuligni S., Mecella M., Tortorelli F. The Italian e-Government Service Oriented Architecture: Strategic Vision and Technical Solutions, Proc. *6th International EGovernment Conference (EGOV 2007)*.

[3] Catarci T., de Leoni M., De Rosa F., Mecella M., Poggi A., Dustdar S., Juszczyk L., Truong H., Vetere G. The WORKPAD P2P Service-Oriented Infrastracture for Emergency Management. Proc. *3rd IEEE International Workshop on Collaborative Service-Oriented P2P System (COPS) at WETICE 2007*.

[4] D'Aprano F., de Leoni M., Mecella, M. Emulating Mobile Ad-hoc Networks of Hand-held Devices. The OCTOPUS Virtual Environment. Proc. *International ACM Workshop on System Evaluation for Mobile Platforms (MobiEval)*, 2007.

[5] De Giacomo G., de Leoni M., Mecella M., Patrizi P. Automatic Workflows Composition of Mobile Services. Proc. *2007 International Conference on Web Services (ICWS 2007)*.

[6] De Giacomo G., Lembo D., Lenzerini M., Rosati R.. On Reconciling Data Exchange, Data Integration, and Peer Data Management. Proc. *26th ACM SIGACT SIGMOD SIGART Symp. on Principles of Database Systems (PODS 2007)*.

[7] De Giacomo G., Patrizi F., Sardina S. Automatic Synthesis of a Global Behavior from Multiple Distributed Behaviors. Proc. *22nd AAAI Conference on Artificial Intelligence (AAAI'07)*.

[8] De Giacomo G., Sardina S. Automatic Synthesis of New Behaviors from a Library of Available Ones. Proc. *20th International Joint Conference on Artificial Intelligence (IJCAI'07)*.

[9] de Leoni M., De Rosa F., Marrella A., Poggi A., Krek A., Manti F. Emergency Management: from User Requirements to a Flexible P2P Architecture. Proc. *4th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2007)*.

[10] de Leoni M., De Rosa F., Mecella M., Dustdar S. Resource Disconnection Management in MANETs Driven by Process Time Plans. Proc. *1st International Conference on Autonomic Computing and Communication Systems (AUTONOMICS 2007)*.

[11] de Leoni M., Mecella M., De Giacomo G. Highly Dynamic Adaptation in Process Management Systems through Execution Monitoring. Proc. *5th International Conference on Business Process Management (BPM 2007)*.

[12] de Leoni M., Mecella M., Russo R. A Bayesian Approach for Disconnection Management in Mobile Ad-hoc Networks. Proc. *4th International Workshop on Interdisciplinary Aspects of Coordination Applied to Pervasive Environments: Models and Applications (CoMA) at WETICE 2007*.

[13] Dragone L., Rosati R. Checking e-Service Consistency using Description Logics. Proc. *2007 IEEE Int. Conference on Services Computing (SCC 2007)*.

Submitted papers, technical reports and others

[14] Baldoni R., Fuligni S., Mecella M., Tortorelli F. The Italian e-Government Enterprise Architecture: A Comprehensive Introduction with Focus on the SLA Issue Proc. ISAS08, 2008 (to appear).

[15] Berardi D., Cheikh F., De Giacomo G., Patrizi F. Automatic Service Composition via Simulation. International Journal of Foundations of Computer Science, 2008 (to appear).

[16] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., Rosati R. Inconsistency Tolerance in P2P Data Integration: an Epistemic Logic Approach. Information Systems, 2008 (to appear).

[17] Catarci T., de Leoni M., Marrella A., Mecella M., Manzoor A., Dustdar S., Juszczyk L., Truong H., Vetere G., Salvatore B. Pervasive Software Environments for Supporting Disaster Responses. IEEE Internet Computing, 2008 (to appear).

[18] Lesperance Y., De Giacomo G., Ozgovde A.N. A Model of Contingent Planning for Agent Programming Languages. Proc. 7th Int. Conference on Autonomous Agents and Multiagent Systems (AAMAS'08), 2008 (to appear).

3.1.6 Distributed Systems

The research activity of the Distributed Systems group focuses on both theoretical and practical aspects of distributed computing, as well as design and performance analysis of middleware technologies. In particular, the group is interested in the following topics:

- Theory of distributed computing.

- Peer-to-Peer Systems
- Middleware

The Distributed Systems group has strong relationships with the most prestigious research institutions worldwide. In 2007, members of the group did joint work with research scientists of the following institutes and industries: INRIA (France), UPM (Spain), LAAS (Toulouse, France), Hebrew University of Jerusalem (Israel), Technion (Haifa, Israel), IBM Haifa (Israel), EPFL (Lousanne, Switzerland), University of Texas at Austin (USA), TELECOM Italia (Italy), SELEX-SI (Italy), University of California Irvine (USA), Univ. of Rennes (France), Technical University of Darmstad (Germany), Univ of Paris VI (France), Cornell Univ. (USA), Technical Univ. of Dresden (Germany), GeorgiaTech (USA), Humbold Univ. (Germany).

Moreover in 2007, Alessia Milani and Leonardo Querzoni finished their PhD program in the context of a co-tutorage with the Univ. of Rennes and the Universidad Politecnica de Madrid (UPM) respectively.

The Distributed Systems group is currently involved in the following research projects: Semantic.gov (EU-IST), ReSIST (EU-IST), ESTEEM (MIUR) and EG4M (MIUR). The group is also involved in the following industrial projects: "QoS for lookup mechanisms in peer-to-peer systems" (Telecom Italia Laboratories), "Implementing the Data Distribution Service specification in wide-area settings" (Selex-SI/Finmeccanica) and "Middleware infrastructures for alarms management in complex systems" (Selex-SEMA/Finmeccanica).

Faculty members: Roberto BALDONI, Roberto BERALDI, Giacomo CIOFFI.
Post-docs: Kleoni IOANNIDOU, Alessia MILANI, Leonardo QUERZONI, Sara TUCCI PIERGIOVANNI.
PhD students: Silvia BONOMI, Adnan Noor MIAN, Sirio SCIPIONI.
Adjunt Researchers: Stefano CIMMINO, Carlo MARCHETTI, Antonino VIRGILLITO.
Visitors: Francois BONNET, Yann BUSNEL, Jean Michel HELARY, Ricardo Jiménez-Peris, Marta PATIÑO-MARTINEZ, Michel RAYNAL, Neeraj SURI.

Theory of Distributed Computing

Distributed Shared Memory. Causal consistency is deeply studied in the context of traditional distributed systems where the number of processes is fixed and a priori known. Traditionally, DSM implementations rely on a distributed memory consistency system (MCS) to enforce a given consistency criterion. Usually the MCS supports complete replication of shared variable at each node accessing the shared memory.

In [32] we investigated the power and the limits of causal memories to support distributed computation, providing several results in the context of traditional causal memories. We adapted the traditional causal consistency criterion to obtain a memory semantics weak enough to be implemented in in emerging distributed systems paradigms (e.g. peer-to-peer systems). but strong enough to allow computational progress.

Dynamic distributed systems. A dynamic distributed system is a fully distributed system subject to a continual arrival/ departure of the very entities defining the system. In this context we firstly investigated the very nature of such systems [7, 23]: while there is an agreement on the definition of what is a static distributed system, there is no agreed definition on what is a dynamic distributed system. This work is a first step in that direction.

Another characterizing dimension of these systems is their possible arbitrary large size (number of entities) and the possible arbitrary small part of the system a single entity directly interacts with. The connectivity of such entities is of fundamental importance to make the whole system

working [15]. We gave a precise definition of the connectivity problem in dynamic distributed systems while formally defining assumptions on arrival/departure of entities and on the evolution of the system size along the time.

Mobile Ad-hoc and sensor networks. These systems represent a challenging environment for the deployment of distributed applications. The mobility of nodes, for mobile ad hoc networks, or the reduced resources available to sensors, for sensor networks, dramatically affect the behaviour of nodes. For these reason well-known solutions from the theory of static distributed systems cannot be applied without modifications.

In this context we started to explore a set of problems to identify their theoretical limits. This study focussed mainly on four different applications: data geocasting [13, 14, 24], coordination among UAVS (unmanned aerial vehicles) for terrain mapping [16], graph exploration with mobile robots [20] and anonymous object and tracking through binary sensor networks [18].

Peer-to-Peer Systems *Unstructured Systems.* P2P systems are at present a widespread technology as well as a hot research topic. *Unstructured* overlay networks have recently emerged as an effective support for large scale dissemination and flooding-based content searching. An unstructured overlay shows good global properties like connectivity (for reliability), low network diameter and constant-degree (for scalability) without relying on a deterministic topology.

Our research in this area has focused on the experimental evaluation of current overlay maintenance protocols in a common framework in order to understand their limits and to make a comparison of different solutions. We investigated the effects of churn in the context of these overlay networks and identified [9] a second effect connected to churn, namely network erosion.

In this context we also studied a family of protocols with many interesting properties, the so called *gossip based* protocols. More specifically we explored [2, 4] the interdisciplinary connections and the composability of such protocols to identify new applications and possible solutions.

DHT-based Structured Systems. Peer-to-peer decentralized systems (P2P) have become extremely popular in the latest years. However, most P2P systems still consist in simple applications such as file sharing or chat systems. The main reason is that complex applications often require powerful communication primitives that nowadays are not offered by P2P systems. Our research work [25] faced this issue addressing the realization of mutual exclusion on top of existing P2P structured overlay infrastructures (Distributed Hash Tables - DHTs).

We also investigated [21] in this context the existence and regularity of logarithmic Harary graphs built through a set of new construction rules.

Middleware

Dependable Middleware. The effective integration of systems and software components that favors and preserves efficiency and dependability gathers growing interest from the research community. In this area, our contributions focus on the design of middleware services enabling the implementation of non-functional requirements such as high availability, load balancing and fault tolerance.

In this context we studied [10] the feasibility of clock synchronization in very large and dynamic settings.using techniques inspired from the biological phenomenon of coupled oscillators.

We also studied in [1] the complexity of the problem of removing Z-Cycles from a checkpoint and communication pattern

Finally, we started to study [29] how well-known communication and synchronization primitives (broadcast and atomic registers) can be implemented in a settings where users and logical

objects can move in a bi-dimensional space and where communication is not always guaranteed due to mobility and range (mobile wireless scenario).

Communication Middleware. Communication middleware infrastructures based on the publish/subscribe paradigm are effective scalable communication systems that allow a large-scale many-to-many interaction involving a huge number of users.

In this context we realized a comprehensive survey of the state-of-the-art in the publish/subscribe area [26]. In particular, we developed a generic layered architecture of a pub/sub system, by identifying and classifying the common elements of any system.

Our studies also focalized on the introduction of advanced clustering techniques aimed at improving the performance of event diffusion mechanisms both in static controlled settings [2] and large scale peer-to-peer environments [6]. These works show how interest-based clustering of system participants is an effective way to greatly reduce the average amount of traffic generated to diffuse each single notification.

Journals

[1] Allulli L., Baldoni R., Laura L., Tucci Piergiovanni S. On the Complexity of Removing Z-cycles from a Checkpoint and Communication Pattern, *IEEE Transactions on Computers*, volume 56, 6, pages 853–858, 2007.

[2] Baldoni R., Beraldi R., Querzoni L., Virgillito A. Efficient Publish/Subscribe through a Self-Organizing Broker Overlay and its Application to SIENA, *The Computer Journal*, volume 50, 4, pages 444–459, 2007.

[3] Baldoni R., Li H., Pereira J., Riviere E. Compositional gossip: a conceptual architecture for designing gossip-based applications, *ACM SIGOPS Operating Systems Review, Special Issue on Gossip-Based Networking*, volume 41, 5, pages 43–50, 2007.

[4] Costa P., Gramoli V., Jelasity M., Jesi G-P., Le Merrer E., Montresor A., Querzoni L. Exploring the interdisciplinary connections of gossip-based systems, *ACM SIGOPS Operating Systems Review, Special Issue on Gossip-Based Networking*, volume 41, 5, pages 51–60, 2007.

Conference proceedings

[5] Bakken D., Baldoni R., Hauser C., Suri N. Towards Compositional ICT for Critical Infrastructure Protection, In *Proceedings of the 37th Annual IEEE/IFIP International Conference on Dependable Systems and Networks* (DSN) Fast Abstract, 2007.

[6] Baldoni R., Beraldi R., Quema V., Querzoni L., Tucci Piergiovanni S. TERA: Topic-based Event Routing for Peer-to-Peer Architectures, In *Proceedings of the 1st Conference on Distributed Event-Based Systems* (DEBS), ACM press, 2-13, 2007.

[7] Baldoni R., Bertier M., Raynal M., Tucci Piergiovanni S. Looking for a Definition of Dynamic Distributed Systems, In *Proceedings of the 9th International Conference on Parallel Computing Technologies* (PaCT), LNCS, 1-14, 2007.

[8] Baldoni R., Bertini F., Lamanna D. Virtual Distro Dispatcher: A Costless Distributed Virtual Environment from Trashware, In *Proceedings of the 5th International Symposium on Parallel and Distributed Processing and Applications* (ISPA), LNCS, 223-234, 2007.

[9] Baldoni R., Bonomi S., Querzoni L., Rippa A., Tucci Piergiovanni S., Virgillito A. Fighting Erosion in Dynamic Large-Scale Overlay Networks, In *Proceedings of the 21st IEEE International Conference on Advanced Information Networking and Applications* (AINA), IEEE Press, 110-117, 2007.

[10] Baldoni R., Corsaro A., Querzoni L., Scipioni S., Tucci Piergiovanni S. An Adaptive Coupling-Based Algorithm for Internal Clock Synchronization of Large Scale Dynamic Systems, In *Proceedings of the 9th International Symposium on Distributed Objects, Middleware, and Applications* (DOA) part of OTM Conferences, LNCS, 701-716, 2007.

[11] Baldoni R., Fuligni S., Mecella M., Tortorelli F. The Italian e-Government Service Oriented Architecture: Strategic Vision and Technical Solutions, In *Proceedings of the 6th International EGov Conference*, 79-88, 2007.

[12] Baldoni R., Hélary J., Tucci Piergiovanni S. A Component Based Methodology to Design Arbitrary Failure Detectors for Distributed Protocols, In *Proceedings of the 10th International Symposium on Object-Oriented Real-Time Distributed Computing* (ISORC), IEEE Press, 51-61, 2007.

[13] Baldoni R., Ioannidou K., Milani A. Mobility versus the Cost of Geocasting in Mobile Ad-Hoc Networks, In *Proceedings of the 21st International Symposium on Distributed Computing*, (DISC), LNCS, 48-62, 2007.

[14] Baldoni R., Ioannidou K., Milani A. Solvability of geocasting in mobile ad-hoc networks, In *Proceedings of the 26th Annual ACM Symposium on Principles of Distributed Computing* (PODC), ACM Press, 386-387, 2007.

[15] Baldoni R., Tucci Piergiovanni S. Connectivity in Eventually Quiescent Dynamic Distributed Systems, In *Proceedings of the 3rd Latin-American Symposium on Dependable Computing* (LADC), LNCS, 38-56, 2007.

[16] Ioannidou K., Milani A. Distributed Aerial Scanning in Mobile Ad-Hoc Networks, In *Proceeding of the 1st International Conference on Autonomic Computing and Communication Systems*, (Autonomics), 2007.

[17] The Esteem Team. Emergent Semantics and Cooperation in Multi-Knowledge Environments: the ESTEEM Architecture in *Proceedings of the International Workshop on Semantic Data and Service Integration (SDSI)*, co-located with VLDB, 2007.

Submitted papers, technical reports and others

[18] Baldoni R., Bertier M., Busnel Y., Kermarrec A., Querzoni L. On the deterministic tracking of moving objects with a binary sensor network, (to appear) In *Proceedings of the 4th IEEE International Conference on Distributed Computing in Sensor Systems* (DCOSS), 2008.

[19] Baldoni R., Bertier M., Busnel Y., Kermarrec A., Querzoni L. Suivi et identification de trajectoires sur un reseau de capteurs binaires (to appear) Algotel, 2008.

[20] Baldoni R., Bonnet F., Milani A., Raynal M. Anonymous graph exploration without collision by mobile robots (submitted to an international journal)

[21] Baldoni R., Bonomi S., Limosani F., Querzoni L., Tucci Piergiovanni S. Investigating the Existence and the Regularity of Logarithmic Harary Graphs, Technical report - MIDLAB 1/08 - Sapienza, Università di Roma, 2008.

[22] Baldoni R., Fuligni S., Mecella M., Tortorelli F. The Italian e-Government Enterprise Architecture: A Comprehensive Introduction with Focus on the SLA Issue Proceedings of ISAS08, LNCS, 2008.

[23] Baldoni R., Helary J., Tucci Piergiovanni S. A Methodology to Design Arbitrary Failure Detectors for Distributed Protocols (to appear) *Journal of Systems Architectures*, 2008

[24] Baldoni R., Ioannidou K., Milani A. Mobility versus the Cost of Geocasting in Mobile Ad-Hoc Networks (submitted to an international journal)

[25] Baldoni R., Jiménez-Peris R., Patino-Martinez M., Querzoni L., Virgillito A. Dynamic quorums for DHT-based enterprise infrastructures. (Accepted for publication) Journal of Parallel and Distributed Computing, 2008.

[26] Baldoni R., Querzoni L., Tarkoma S., Virgillito A. Distributed event routing in publish/subscribe communication systems, (to appear) In Garbinato B., Miranda H. and Rodriguez L., editor, MiNEMA State-of-the-Art Book. Springer Berlin / Heidelberg, 2008.

[27] Beraldi R. The polarized gossip protocol for path discovery in MANETs, (to appear) *Ad Hoc Networks* 6(1)79-91, 2008.

[28] Beraldi R., Querzoni L., Baldoni R. Low hitting time random walks in wireless networks, (to appear) *Wireless Communications and Mobile Computing*, 2008.

[29] Bonnet F., Bonomi S., Killijian M., Querzoni L., Scipioni S., Tucci Piergiovanni S. FADA: Formalisms and Algorithms for Resilient Services Design in Ambient Systems, (to appear) In *Proceedings of the 7th European Dependable Computing Conference* (EDCC), Fast Abstracts, 2008.

[30] Mian A. N., Beraldi R., Baldoni R. A Robust and Energy Efficient Protocol for Random Walk in Ad hoc Networks with IEEE 802.11 (to appear) In (to appear) *Proceedings of the 7th International Workshop on Performance Modeling, Evaluation, and Optimization of Ubiquitous Computing and Networked Systems*, 2008.

[31] Mian A. N., Beraldi R., Baldoni R. A Closer Investigation of Service Discovery Protocols in Mulithop Mobile Ad Hoc Networks (Submitted to an international journal)

Ph.D. thesis

[32] A. Milani. *Causal Consistency in static and dynamic distributed systems*, PhD Thesis, Dipartimento di Informatica e Sistemistica A. Ruberti, Sapienza Università di Roma, 2007.

[33] L. Querzoni. *Techniques for Efficient Event Routing*, PhD Thesis, Dipartimento di Informatica e Sistemistica A. Ruberti, Sapienza Università di Roma, 2007.

3.1.7 Parallel and Distributed Computing

The research activity of the Parallel and Distributed Computing group focuses on various aspects of computing and service oriented applications and platforms, spanning from theory to modeling, design and implementation. In particular, the group is interested in the following topics:

- Dependable (Web-based) distributed systems.
- High performance and QoS oriented (Web-based) distributed systems
- Parallel/distributed simulation systems.
- Federated simulation systems.
- Parallel computing applications and platforms.
- System Modeling and optimization.

Currently, members of the Parallel and Distributed Computing group are cooperating with several prestigious national and international research institutions: IAC-CNR (Italian National Research Council), IRIANC (International Research Institute for Autonomic Network Computing - Boston USA), IBM Research Center T.J. Watson (USA), Georgia Institute of Technology (USA), INESC-ID (Istituto Superior Tecnico) Lisboa - Portugal. Some of the members of the group are also co-founders of IRIANC.
The Parallel and Distributed Computing group is presently involved in the following research projects: MURST FIRB "In.Sy.Eme - Integrated System for Emergency", ATENEO "Transparent Optimistic Synchronization in HLA-based Distributed Applications".

Group members
Faculty members: Francesco QUAGLIA, Bruno CICIANI.
PostDoc: Paolo ROMANO, Andrea SANTORO.

Dependable (Web-based) Distributed Systems Modern transactional applications (e.g. e-Commerce applications) are typically structured according to a multi-tier system organization, where middle-tier application servers have the responsibility to interact with back-end databases on behalf of the client (e.g. an applet running in a browser). The partitioning of an application into multiple tiers provides the potential to achieve high modularity and flexibility. On the other hand, the multiplicity and diversity of the employed components, and their interdependencies, makes it not trivial to achieve meaningful forms of reliability.

Our focus is on reliability in multi-tier systems with stateless middle-tier servers, in their most general configuration where the application logic is allowed to execute atomic transactions against a set of autonomous distributed back-end databases, e.g., as in the context of multiple parties involved within the same business process. For this kind of systems, some authors have recently proposed a reliability framework called e-Transaction (exactly-once Transaction), which is specified via a set of seven properties belonging to the following three categories: *Termination*, *Agreement* and *Validity*.

In this context we have proposed innovative e-Transaction protocols that reveal performance effective (i.e. they requires less, or at most the same, message rounds and eager logs as literature protocols), and that have the distinguishing feature of ensuring the e-Transaction properties while relying on less strict, or even no assumptions on the accuracy of failure detection, hence being employable in a pure asynchronous system. Compared to state of the art protocols, our proposals are suited for a wider class of distributed systems, encompassing general (large scale) Web infrastructures layered on public networks over the Internet, possibly owned by providers offering different levels of guarantees, or even no guarantee at all, on, e.g., the message transmission delay.

High Performance and QoS Oriented (Web-based) Distributed Systems Quality-of-Service (QoS) provisioning in the Internet has been a topic of active research in the last few years. However, due to both financial and technical reasons, the proposed solutions are not commonly employed in practice. As a consequence, in general settings, the Internet architecture is still mainly oriented to a best effort delivery model, which does not provide any guarantee neither on the message delivery latency, nor on the probability that a service residing at some host becomes temporarily unreachable due to network congestion. In this context, we have presented innovative, application level protocols tailored for Web transactional applications (e.g. e-Commerce applications), which attempt to reduce the impact of network congestion on the latency experienced by the end users. The intuition underlying our proposals is to exploit the intrinsic potential of parallelism commonly exhibited by Application Service Providers (ASPs) infrastructures, where

the application access point is replicated over a large number of geographically distributed edge servers. At this purpose we allow privileged classes of users to concurrently contact multiple, replicated access points so to increase the probability to timely reach at least one of them and promptly activate the application business logic for the interaction with back-end database systems. We complete our proposals with efficient mechanisms that prevents multiple, undesired updates on the back-end databases and, at the same time, strongly limit the additional load on the ASP infrastructure due to the increased amount of requests from the privileged users.

Parallel/distributed simulation systems Optimistic methods for parallel/distributed simulation let concurrent processes execute simulation events whenever they are available, optimistically assuming that the execution does not violate causality. Checkpoint-based rollback is used to recover from out of order computations.

In this context, we recently studied how to reuse checkpoints taken in an uncorrelated manner during the forward execution phase in order to construct global consistent snapshots which are also committed (i.e. the logical time they refer to is lower than the current Global-Virtual-Time - GVT - value). This has been done by introducing a heuristic-based mechanism relying on update operations applied to local committed checkpoints of the involved simulation objects so to eliminate mutual dependencies among the final achieved state values. The mechanism is lightweight since it does not require any form of (distributed) coordination to determine which are the checkpoint update operations to be performed. Our proposal can support, in a performance effective manner, termination detection schemes based on global predicates evaluated on a committed and consistent global snapshot, which represent an alternative as relevant as classical termination check only relying on the current GVT value. Another application concerns interactive simulation environments, where (aggregate) output information about committed and consistent snapshots needs to be frequently provided, hence requiring lightweight mechanisms for the construction of the snapshots.

Another relevant problem we have addressed is related to checkpoint/restore facilities for optimistic simulation objects with generic memory layout. Specifically, we have presented the design and implementation of a `C` library, named DyMeLoR (Dynamic Memory Logger and Restorer), that, beyond offering traditional services for dynamic memory allocation/release, additionally supports transparent checkpoint/restore of scattered simulation objects' states. From the point of view of efficiency, DyMeLoR has been designed in order to minimize memory consumption for meta-data describing the current layout of the simulation object's state, and to provide good trade-offs between the cost of meta-data manipulation and the cost of memory-to-memory data copies associated with checkpoint/restore tasks. Also, the library exhibits Piece-Wise-Deterministic (PWD) behavior, thus allowing the employment of (optimized) sparse checkpointing strategies each time the overlying application software complies with the PWD assumption.

Federated simulation systems The High Level Architecture (HLA) is a standard for the integration and the interoperability of autonomous simulators. Its target is the building of complex simulation systems (federations in the HLA terminology) through the use of a Run-Time Infrastructure (RTI) acting as a middleware component, which offers a general set of services to each involved simulator (i.e. to each federate). A major problem to address in HLA federations is how to efficiently ensure correct order (i.e. timestamp ordering) for the execution of simulation events at each involved federate. This is also referred to as the synchronization problem. To cope with this problem, we have designed and implemented a Time Management Converter (TiMaC) for HLA based simulation systems. TiMaC is a layer interposed in between the federate and the underlying RTI in order to map the conservative (simple to use) Time-Management interface onto

the optimistic one (more prone to performance effectiveness). Then we have also investigated optimistic oriented intermediate approaches to synchronization, embedding the aggressiveness property of optimistic systems (hence simulation events can be speculatively executed without preventive assurance of their safety), but discarding risk (hence no message is ever sent out towards remote federates unless it is a committed message). To support such a kind of optimistic oriented synchronization scheme we have developed a middleware layer resulting as the evolution of TiMaC, referred to as Risk-Free-Speculator (RFS).

Another approach to reduce the message overhead connected with the publish/subscribe mechanism adopted by HLA, which we have investigated, deals with the exploitation of the advanced capabilities of modern network cards to move part of the computation related to the publish/subscribe management inside the network card. This allows the CPU to execute actual computation instead of the network overhead often associated with pub/sub systems.

Finally, we have also explored software diversity and active replication of application level simulation components, so to allow the whole HLA simulation system to take performance advantages from the "best instant responsiveness" among all the involved replicas. Beyond providing the framework for software diversity-based replication, we propose the design and implementation of an Active Replication Management Layer (ARML), which transparently supports software diversity-based replicas of a same HLA federate simulator, by showing them as a single logical entity. The implementation of ARML has been based on `C` technology and standard POSIX APIs. Hence it results portable across any kind of POSIX compliant operating system (e.g. UNIX systems).

Parallel Computing Applications and Platforms Recent results in the field of functional programming have shown how the reduction of λ-terms can be mapped onto a particular graph rewriting technique known as Directed Virtual Reduction (DVR). In this technique each computational step corresponds to a transition from a graph G to a graph G' obtained through the *composition* of two labeled edges insisting on the same node. Typically such a composition originates additional nodes and edges within the graph.

By exploiting DVR we have developed PELCR, namely a Parallel Environment for Lambda-Calculus Reduction, which allows edge compositions to be performed concurrently by supporting the graph distribution among multiple machines. This environment relies on a strategy for DVR, namely *half combustion*, which we have introduced to achieve a higher level of intrinsic parallelism in the edge composition. While developing PELCR we have adopted both a message aggregation technique, allowing a reduction of the communication overhead, and a fair policy for distributing dynamically originated load among processors. Additionally, we have used a set of other optimizations, e.g. allowing the maintenance of relatively low size for the manipulated data structures so not to incur problems related to their management at the application level or due to the management of large process memory images at the operating system level. As a last note, the software modules composing PELCR have been developed with the `C` language and using a standard interface for message passing, i.e. MPI, thus making PELCR itself a highly portable software package.

System Modeling and Optimization One of the most used models for incoming traffic in networked systems, such as the GRID and the WWW, is the Markov Modulated Poisson Process ($MMPP$). A Markov Modulated Poisson Process is simply a Poisson Process whose mean value changes according to the evolution of a Markov Chain. In this context, we have studied and discussed the possibility to approximate the behavior of an $MMPP/M/1$ queue analytically, thus saving the large amount of calculations required to evaluate the same data by other means. The method employed consists in approximating the $MMPP/M/1$ queue as a weighted superposi-

tion of different $M/M/1$ queues. Since it is an approximation, we derive a methodology to decide in what instances the approximation is useful.

Concerning analytical results, we have also provided a performance model for Multi-Version Concurrency Control (MVCC) in database systems. This type of concurrency control is supported by several commercial and open source database systems (including Oracle and PosgreSQL), and is highly attractive due to its ability to well cope with read intensive workloads, as in the case of transaction profiles proper of Web applications. To build the model we had to tackle the intrinsic higher complexity of MVCC, when compared to traditional concurrency control mechanisms (i.e. two-phase locking and optimistic ones), such as the joint use of locks and aborts to resolve direct conflicts on write accesses to the same data item, and the management of multiple data versions. We have also presented an extensive simulation study, with both uniform and skewed data accesses, and with differentiated transaction profiles, in order to support model validation. To the best of our knowledge, the presented study provides the first analytical model of MVCC.

Journals

[1] Pedicini M. and Quaglia F., PELCR: Parallel Environment for Optimal Lambda-Calculus Reduction. *ACM Transactions on Computational Logic*, vol.8., no.3, Article 14 (pp.1-36), 2007.

[2] Quaglia F., Software Diversity-Based Active Replication as an Approach for Enhancing the Performance of Advanced Simulation Systems. *International Journal of Foundations of Computer Science*, vol.18, no.3, pp.495-515, 2007.

[3] Quaglia F. and Romano P., Ensuring e-Transaction with Asynchronous and Uncoordinated Application Server Replicas. *IEEE Transactions on Parallel and Distributed Systems*, vol.18, no.3, pp.364-378, 2007.

[4] Santoro A. and Quaglia F., Multiprogrammed Non-blocking Checkpoints in Support of Optimistic Simulation on Myrinet Clusters, *Journal of Systems Architecture*, vol.53, no.9, pp.659-676, 2007.

Conference proceedings

[5] Ciciani B., Santoro A. and Romano P., Approximate Analytical Models for Networked Servers Subject to MMPP Arrival Processes, *Proc. 6th IEEE International Symposium on Network Computing and Applications (NCA)*, Cambridge, MA, USA, IEEE Computer Society Press, July 2007. Winner of the **Best Paper Award**.

[6] Cucuzzo D., D'Alessio S., Quaglia F. and Romano P., A Lightweight Heuristic-based Mechanism for Collecting Committed Consistent Global States in Optimistic Simulation, *Proc. 11th IEEE/ACM International Symposium on Distributed Simulation and Real-Time Applications (DS-RT)*, IEEE Computer Society Press, Chania, Crete Island, Greece, October 2007.

[7] Quaglia F. and Santoro A., Transparent Risk-free Synchronization in the High-Level-Architecture Interoperability Standard, *Proc. 12th IEEE International Symposium on Computers and Communications (ISCC)*, IEEE Computer Society Press, Aveiro, Portugal, July 2007.

Submitted papers, technical reports and others

[8] Di Sanzo P., Ciciani B., Quaglia F. and Romano P., A Performance Model of Multiversion Concurrency Control, submitted to an international conference.

[9] Romano P., Ciciani B., Santoro A. and Quaglia F., Fast Computation of Hyper-exponential Approximations of the Response Time Distribution of MMPP/M/1 Queues, *Proc. 41st IEEE Annual Simulation Symposium (ANSS)*, Ottawa, Canada, IEEE Computer Society Press, April 2008, to appear.

[10] Romano P., Ciciani B., Santoro A. and Quaglia F., Accuracy vs Efficiency of Hyper-exponential Approximations of the Response Time Distributions of MMPP/M/1 Queues, *Proc. 21st EEE International Parallel and Distributed Processing Symposium - DPDNS Workshop (IPDPS)*, Miami, USA, IEEE Computer Society Press, April 2008, to appear.

[11] Romano P. and Quaglia F., Integration and Evaluation of Multi-Instance-Precommit Schemes within PostgreSQL , *Proc. 38th IEEE/IFIP International Conference on Dependable Systems and Networks (DSN)*, Anchorage, Alaska, USA, IEEE Computer Society Press, June 2008, to appear.

[12] Romano P. and Quaglia F., Providing e-Transaction Guarantees with no Assumptions on the Accuracy of Failure Detection, *IEEE Transactions on Dependable and Secure Computing*, pending revision.

[13] Romano P. and Quaglia F., Parallel Invocation Schemes for QoS-oriented Multi-tier Transactional Applications, in preparation for submission to an internation journal.

[14] Romano P., Rughetti D., Quaglia F. and Ciciani B., APART: Low Cost Active Replication in Data Acquisition Systems, *Proc. 7th IEEE International Symposium on Network Computing and Applications (NCA)*, Cambridge, MA, USA, July 2008, to appear.

[15] Santoro A. and Fujimoto R.M., Off-Loading Data Distribution Management to Network Processors in HLA-Based Distributed Simulations, *IEEE Transactions on Parallel and Distributed Systems*, Vol.19, no.3, March 2008, to appear.

[16] Santoro A. and Quaglia F., Transparent Optimistic Synchronization in the High-Level-Architecture via Time Management Conversion, in preparation for submission to an internation journal.

[17] Toccaceli R. and Quaglia F., DyMeLoR: Dynamic Memory Logger and Restorer Library for Optimistic Simulation Objects with Generic Memory Layout, *Proc. 22nd ACM/IEEE/SCS Workshop on Principles of Advanced and Distributed Simulation (PADS)*, Rome, Italy, IEEE Computer Society Press, June 2008, to appear.

3.1.8 Programming Languages and Methodologies

Faculty members Marco TEMPERINI.

Our group hosts the research activities of a number of scientists, coming from other departments of Sapienza Università di Roma and from other universities. Members of the group, other than Faculty, are pointed out in the following descriptions of research activities. We work on

1. the development of methodological and applicative aspects of the *Open and Distance Learning*. In this area, the most recent EU research initiatives in which we participated is the *QUIS* project (QUality, Interoperability and Standards in e-learning), Agreement n. 2004 – 3538 /001 – 001 ELE–ELEB14, 2005/2007, `http://www.tisip.no/quis/`.
2. the principles of object-oriented programming languages and their applications in distributed (object-oriented) programming;
3. the application of ICT to collaborative working and participative planning;

Open and Distance Learning In collaboration with M. De Marsico and A. Sterbini (DI - Sapienza Università di Roma), and C. Limongelli (DIA - Università di Roma Tre), we work on the *automated configuration of courses* (tailored on the individual learning needs): We extended our approach with the definition of *learning objective templates*. That allows for a formal definition of curriculi, which are presently expressible only through informal (verbal) learning objectives ([4, 5]). We devised different implementations, basing on logic programming ([10]) and automated planning ([7, 8]). We extended the latter applications by issues related to standards for e-learning (SCORM). Our activity into EU initiatives, led to [1, 2, 6]. Our activity on web support to collaborative work in education, brought to a reputation system for the production/exchange of course exercises at university level ([9]).

Distributed object-oriented programming Being interested in inheritance in object-oriented programming, we have started an activity on the application of inheritance into distributed object-oriented programming environments. We devised support for *remote inheritance* (i.e. the definition and use of class hierarchies distributed throughout a set of computing sites). A class (hierarchy) is defined in a server and clients can use it in their local programming; when a class is updated, each client will eventually (automatically) reload and update its code. The activity on this subject is conducted so far through development of *Laurea* thesis. After approaches based on the use of *RMIClassLoader* and *Aglets*, we are analysing other technologies, such as *JavaSpace Server* and *Jiny* to support the exchange and update of remotely maintained classes into local applications

Support to collaborative working and participation planning In collaboration with Alberto Budoni (DAU - Sapienza Università di Roma) and Luciano De Bonis (Dip. SAVA, Università del Molise), we pursue an interdisciplinary activity focused on the design and development of a prototypal web application supporting public discussion about environmental and territorial projects (*plans*). The web-site provides the users with means to express and collect opinions; one further aim is to allow for content analysis to both support decision making and represent the so-called *image* that the community shares about its urban/territorial environment. [3] has been elected among the best in the UDMS conference and invited for a special issue of the Elsevier Journal on Computers, Environment and Urban Systems (CEUS, [11]).

Books

[1] De Marsico M., Temperini M. Data Specification for the Definition of a Topic Map on Standards. The TISIP Research Foundation, Trondheim, Norway. ISBN: 978-82-8055-035-4. (2007).

[2] Di Domenico F., Sterbini A., Temperini M. Analysis of Commercial and Experimental e-learning Systems. The TISIP Research Foundation, Trondheim, Norway. 2nd ed. ISBN: 978-82-8055-027-9. (2007).

Conference proceedings

[3] Budoni A., De Bonis L., Federici P.A., Maurelli P., Temperini M. Integration of Webgis and Open Content Environments for Self-empowering e-Governance. 26th International Symposium of Urban Data Management, 10th-12th October 2007, Stuttgart, Germany (2007)

[4] Fernandez G., Sterbini A., Temperini M. On the Specification of Learning Objectives for Course Configuration 6th Int. Conference on Web-Based Education (WBE 2007), Mar 14-16, 2007, Chamonix, France. ISBN/ISSN: 978-0-88986-650-8 (2007)

[5] Fernandez G., Sterbini A., Temperini M. Learning Objects: A Metadata Approach. The IEEE Region 8 Eurocon 2007 Conference September 9-12, 2007, Warsaw, Poland (2007)

[6] Kolås L., Staupe A., Sterbini A., Temperini M. The QUIS Requirement Specification of a Next Generation E-Learning System. In Proc. e-Learning 2007, IADIS International Conference, 6th-8th July 2007, Lisbon, Portugal (2007)

[7] Limongelli C., Sampietro G., Temperini M. UNITAG: Extending Moodle Functionalities to Create Personalized Courses by Means of Automated Planning. *Special Session on Standards* - 8th International Conference on Information Technology Based Higher Education and Training (ITHET2007) 10th-13th July 2007, Kumamoto, Japan (2007)

[8] Limongelli C., Sampietro G., Temperini M. Configuration of Personalized e-Learning Courses in Moodle. The IEEE Region 8 Eurocon 2007 Conference September 9-12, 2007, Warsaw, Poland (2007)

[9] Sterbini A., Temperini M. Good students help each other: improving knowledge sharing through reputation systems. 8th International Conference on Information Technology Based Higher Education and Training (ITHET2007) 10th-13th July 2007, Kumamoto, Japan (2007)

[10] Temperini M., Vitti U. A Web Application for Automated Course Configuration. 8th International Conference on Information Technology Based Higher Education and Training (ITHET2007) 10th-13th July 2007, Kumamoto, Japan (2007)

Submitted papers, technical reports and others

[11] Budoni A., De Bonis L., Federici P.A., Maurelli P., Temperini M. Webgis and Open Content Environments in an integrated architecture: concepts and experimentations for Self-empowering e-Governance. *J. of Computers, Environment and Urban Systems*, Elsevier, Special issue on UDMS. submitted

3.2 Systems Science

3.2.1 Biomedical Systems

The research activity in this scientific area lies, at present, in two main projects: analysis and modelling of metabolic systems and analysis of brain potentials related to motor control.

The group complrises people from different institutions: IASI-CNR, Roma; Istituto di Clinica Medica-Policlinico A. Gemelli, Università Cattolica del Sacro Cuore, Roma; Istituto di Fisiologia Umana, Sapienza Università di Roma; IRCCS S. Lucia, Roma.

Group members
Faculty members Serenella SALINARI.
Post-docs Laura ASTOLFI.
PhD student Bioengineering Eugenio MATTEI.
PhD student System Science Simone ASNAGHI.

Analysis and Modelling of Metabolic Systems During the last year, the interest was mainly focused on: i) the analysis of the glucose and lipid metabolism and their interaction in healthy and obese/diabetic subjects; ii) the mechanisms underlying the glucose-stimulated insulin secretion.

i) Data of multiple-meal experiments were analyzed by a mathematical model describing the dual control of insulin release by glucose and FFA [9]. Parameters of β-cell function were estimated in control subjects as compared to obese patients before and after diet. The model is based on the experimental evidence that a source of fatty acids (FAs) either exogenous or endogenous is necessary to support normal insulin secretion. Therefore, FAs co-modulate the glucose-induced pancreatic insulin secretion. On the basis of this model we also investigated the role of FFA in the prompt normalization of β-cell glucose sensitivity after a malabsorptive bariatric surgery (Bilio Pancreatic Diversion) [19].

In the same context, a mathematical model representing the dynamics of intracellular insulin granules in β-cells was also proposed [6]. The model provides an interpretation of the roles of the triggering and amplifying pathways of glucose-stimulated insulin secretion.

Analysis of Brain Potential related to Motor Control In the last year, the research activity involved problems connected with i) the estimation of the effective and functional human cortical connectivity and ii) the utilization of the estimated cortical activity in some applicative contexts such as the implementation of Brain Computer Interface (BCI) devices and the analysis of the brain potential modifications in patients affected by the Alzheimer disease (AD).

i) The concept of brain connectivity (defined as the simplest brain circuit that would produce the same temporal relationship as observed experimentally between cortical sites) plays today a central role in the neuroscience. In the last year the aim of the work was devoted to characterize quantitatively the performance of a time-varying multivariate method for the estimation of rapidly changing connectivity relationships between cortical areas of the human brain, and to apply it to a set of real high resolution EEG data. This approach will allow the observation of rapidly changing influences between the cortical areas during the execution of a task [2, 12, 15]. In the same context a set of computational tools able to estimate cortical activity and connectivity from high-resolution EEG and fMRI recordings in humans were implemented. The present findings suggest that the methodology is able to identify differences in functional connectivity patterns elicited by different experimental tasks or conditions [3, 7, 8, 13, 14, 18]. Connectivity pattern estimators investigated are the Directed Transfer Function (DTF), its modification known as direct DTF (dDTF) and the Partial Directed Coherence (PDC) [1].

ii) In order to analyze whether the use of the cortical activity, estimated from non invasive EEG recordings, could be useful to detect mental states related to the imagination of limb movements, we estimated cortical activity from high-resolution EEG recordings in a group of healthy subjects by using realistic head models. [10, 11]. This approach was applied, in the field of the BCI methodology, in a group of disabled patients in order to give them a suitable control of several electronic devices disposed in a three-room environment devoted to the neurorehabilitation [3]. With reference to the analysis on the Alzheimer disease (AD), in the last year the study was aimed to test different hypothesis correlated with alterations of resting electroencephalographic (EEG) rhythms across the continuum of healthy elderly (Hold), mild cognitive impairment (MCI), and AD subjects [4, 16, 17].

Journals

[1] Astolfi L., Cincotti F., Mattia D., Marciani M.G., Baccala L., De Vico Fallani F., Salinari S., Ursino M., Zavaglia M., Ding L., Edgar J.C., Miller G.A., He B., Babiloni F. Comparison of different cortical connectivity estimators for high resolution EEG recordings. *Human brain mapping*, vol. 28, pp. 143-157, 2007.

[2] Astolfi L, Bakardjian H, Cincotti F, Mattia D, Marciani Mg, De Vico Fallani F, Colosimo A, Salinari S., Miwakeichi F, Yamaguchi Y, Martinez P, Cichocki A, Tocci A, Babiloni F. Estimate of Causality Between Independent Cortical Spatial patterns during movement volition in spinal cord injured patients. *Brain topography*, vol. 19(3), pp.107-123, 2007.

[3] Astolfi L, De Vico Fallani F, Cincotti F, Mattia D, Marciani Mg, Bufalari S, Salinari S., Colosimo A, Ding L, Edgar Jc, Heller W, Miller Ga, He B, Babiloni F. Imaging functional brain connectivity patterns from high-resolution EEG and fMRI via graph theory. *Psychophysiology*, vol. 44, pp. 880-893, 2007.

[4] Babiloni C, Squitti R, Del Percio C, Cassetta E, Ventriglia Mc, Ferreri F, Tombini M, Frisoni G, Binetti G, Gurz, M, Salinari S., Zappasodi F, Rossini PM. Free copper and resting temporal EEG rhythms correlate across healthy, mild cognitive impairment, and Alzheimer's disease subjects. *Human brain mapping*, vol. 28, pp.143-157, 2007.

[5] Babiloni F, Cincotti F, Marciani M, Salinari S, Astolfi L, Tocci A, Aloise F, Fallani Fde V, Bufalari S, Mattia D. The estimation of cortical activity for brain-computer interface: applications in a domotic context. *Computational intelligence and neuroscience*, vol. 2007, pp. 91651, 2007.

[6] Bertuzzi A., Salinari S., Mingrone G. Insulin granule trafficking in b-cells: mathematical model of glucose-induced insulin secretion *American Journal of physiology E&M*, vol. 293, pp. E396-E409, 2007.

[7] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Tocci A, Marciani Mg, Colosimo A, Salinari S., Gao S, Cichocki A, Babiloni F. Extracting information from cortical connectivity patterns estimated from high resolution EEG recordings: a theoretical graph approach. *Brain topography.* , vol. 19(3), pp. 125-136, 2007.

[8] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Marciani Mg, Salinari S., Kurths J, Gao S, Cichocki A, Colosimo A, Babiloni F. Cortical functional connectivity networks in normal and spinal cord injured patients: Evaluation by graph analysis. *Human brain mapping.* , vol. 28, pp. 1334-1346, 2007.

[9] Salinari S, Bertuzzi A, Manco M, Mingrone G NEFA-Glucose co-modulation model of beta-cell insulin secretion in 24-hour multiple meal test. *American journal of physiology E&M* , vol. 292, pp. E1890-E1898, 2007.

Articles in books

[10] Cincotti F, Mattia D, Bianchi L, Salinari S, Marciani M.G, Babiloni F. Estimation of cortical activity for non invasive EEG recordings for Brain Computer Interface applications. *In Akay M. and He B.: Handbook of Neural Engineering. NEW YORK: John Wiley & Sons*, 2007.

[11] Cincotti F, Mattia D, Timperi A, Mattiocco M, Bianchi L, Salinari S, Marciani M.G, Babiloni F. The use of high resolution EEG for brain computer interface applications. *In Akay M. and He B.: Handbook of Neural Engineering. NEW YORK: John Wiley & Sons*, 2007.

Conference proceedings

[12] Astolfi L, Cincotti F, Mattia D, De Vico Fallani F, Colosimo A, Salinari S., Marciani Mg, Ursino M, Zavaglia M, Hesse W, Witte H, Babiloni F. Time-varying cortical connectivity by adaptive multivariate estimators applied to a combined foot-lips movement. *Conf Proc IEEE Eng Med Biol Soc. 2007. Sciences and Technologies for Health.* Aug. 2007 Page(s): 4402-4405

[13] Babiloni F, Astolfi L, Cincotti F, Mattia D, Tocci A, Tarantino A, Marciani M, Salinari S., Gao S, Colosimo A, De Vico Fallani F. Cortical activity and connectivity of human brain during the prisoner's dilemma: an EEG hyperscanning study. *Conf Proc IEEE Eng Med Biol Soc. 2007. Sciences and Technologies for Health.* Aug. 2007 Page(s): 4593-4596

[14] Babiloni F, Cincotti F, Mattia D, De Vico Fallani F, Tocci A, Bianchi L, Salinari S., Marciani M, Colosimo A, Astolfi L. High resolution EEG hyperscanning during a card game. *Conf Proc IEEE Eng Med Biol Soc. 2007. Sciences and Technologies for Health.* Aug. 2007 Page(s): 4957-4960

Submitted papers, technical reports and others

[15] Astolfi L, Cincotti F, Mattia D, De Vico Fallani F, Tocci A, Colosimo A, Salinari S, Marciani MG, Hesse W, Witte H, Ursino M, Zavaglia M, Babiloni F. Tracking the time-varying cortical connectivity patterns by adaptive multivariate estimators *IEEE Trans Biomed Eng.*, vol. 55(3), pp. 902-913.2008

[16] Babiloni C, Ferri R, Binetti G, Vecchio F, Frisoni Gb, Lanuzza B, Miniussi C, Nobili F, Rodriguez G, Rundo F, Cassarino A, Infarinato F, Cassetta E, Salinari S., Eusebi F, Rossini . Directionality of EEG synchronization in Alzheimer's disease subjects. *Neurobiology of aging*. Epub 14/6/2007.

[17] Babiloni C, Frisoni GB, Pievani M, Vecchio F, Infarinato F, Geroldi C, Salinari S, Ferri R, Fracassi C, Eusebi F, Rossini PM. White matter vascular lesions are related to parietal-to-frontal coupling of EEG rhythms in mild cognitive impairment. *Human brain mapping*. Epub 2/11/2007.

[18] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Marciani Mg, Tocci A, Salinari S., Witte H, Hesse W, Gao S, Colosimo A, Babiloni F. Cortical Network Dynamics during Foot Movements *Neuroinformatics*. E-pub 12/2/2008.

[19] Salinari S., Bertuzzi A., Iaconelli A., Manco M., Mingrone G. 24-h insulin secretion and beta cell NEFA oxidation in type 2 diabetic, morbidly obese subjects before and after bariatric surgery. *Diabetologia.* In press.

[20] Salinari S. Ingegneria Biomedica. *Enciclopedia della scienza e della tecnica.* Istituto dell'Enciclopedia Italiana (Treccani). In press.

3.2.2 Hybrid Systems

The research activities of the group cover several topics ranging from the integration of hard computing and soft computing techniques, nonlinear digital and switching systems as well as sensors and measurements, non conventional approaches to modeling, analysis, identification and control of dynamical systems from different areas.

Indeed the title itself of this research group summarizes the variety of methodologies and application fields. The common frame stands in overcoming and broadening the conventional approach in the analysis and design of complex dynamical systems.

Research projects include:

"Stima dei Parametri nelle reti di trasmissione dell'energia" supported by Terna Spa;

The Business Lab - E.schermatica, supported by Filas (Finanziaria Laziale di sviluppo).

Collaborations include: the Laboratoire des Signaux et Systèmes, CNRS, Ecole Supérieure d'Electricité, Gif-sur-Yvette, Department of Electrical Engineering, University of L'Aquila.

Faculty Members: Claudia CALIFANO, Alessandro DE CARLI, Paolo DI GIAMBERARDINO, Claudio GORI GIORGI, Salvatore MONACO,
Post Docs: Roberto RONCHINI
PhD Students: Gianluigi BALDESI, Filippo FABBRI, Simone GABRIELE, Andrea USAI.

Emergent and innovative control strategies The research activity involved problems connected to the design of intelligent controllers at higher level in the organization of Industrial automation and autonomous navigation in unknown environments.

Publications in this area concern the systematic and structured organization of the design procedure for a complex system as well as well as the use in this context of the UML language [2]. In [1], [3] open problems are discussed and possible approaches are proposed.

Discrete-time systems The contributions in this area are concerned with the exact and approximate feedback linearization, observer design, normal forms and more generally with the analysis of discrete time systems through the use of its differential difference representation. More in detail in [6] the formalism of chronological calculus for studying time-varying differential equations has been extended to the analysis of discrete-time dynamics. It is shown that the chronological exponential admits an ordinary exponential representation, the exponent being given by an explicitely computable Lie series expansion. The obtained results have then been used to describe controlled dynamics, dynamics under sampling and forced discrete-time dynamics. The performed study emphasizes the role of Lie algebra techniques in nonlinear control theory and specifies structural similarities between nonautonomous differential equations, dynamics under sampling and forced discrete-time dynamics up to hybrid ones. Controller and observer normal forms are discussed in [21], where it is shown that the use of the Difference/Differential Representation allows to characterize the link between the resonance terms contained in these forms and the obstruction to the geoemtric properties ensuring feedback linearization or observer design with linear error dynamics. The Difference/Differential Representation has been used with respect to the observer problem also in [7]. In [8] , the equivalence under coordinates change and output transformation to observer canonical forms is analyzed for discrete time systems with two outputs, while the general case is addressed in [19].

Digital and switching control Digital control methods, from emulation of continuous controllers to sampe data design, require the knowledge of the discrete time model of the plant. With respect to this problem, in [5] it has been shown how series expansions associated to fomal integration can be profitably used in order to handle generalized sample procedures. Based on this

approach constructive procedures for the computation of the proposed digital solutions. Several other contributions deal with the investigation of the properties of the sampled model in order to get new insights and ideas for the design of digital control schemes. This is the case of the characterization of the accessibility property under multirate sampling in [12], of the digital controller inversion in [13], of the characterization of the properties under sampling for the linearization by output onjection in [14] and of the input state matching under multirate sampling in [22].

Sensors and Measurements It is well known that measurements represent the very critical part of any control problem, and a lot of work has been done for improving all the components and processes involved, from sensors to transmission, from filtering to manipulation/elaboration, from data storage to data presentation. Moreover, in several problems the acquisition of measurements represents the most important part of high level control schemes, like monitoring or surveillance tasks. In these schemes, distributed sensors systems and networks are assuming a more and more important role. Combining measurement systems with autonomous mobility, the idea of dynamic sensor networks was born. Within this framework, a mobile platform carrying some sensors is seen as an intelligent composite sensor; the coordination of some of them produce a dynamic network, with several capabilities clearly not owned by static networks. The formalization of such measurement processes, often intrinsically hybrid, often makes easier the solution of problems like surveillance, monitoring, data acquisition over large areas and so on, and can simplify problems of decentralized or distributed control. Contributions in this field concern sensor and actuator devices, computation algorithms and control. In [4] the idea of dynamic sensor networks has been formalized and an approach to the field coverage problem, afterwards extended in [10], has been given. Within the same context, in [11] the communications problems in dynamic sensor networks has been addressed. For the mobility aspects, the use of visual feedback for motion planning and control of nonholonomic mobile platforms has been presented in [15]. In [9] a new kind of devices, called Ionic Polimer Metal Composites, that can work as sensor and as actuators, have been addressed, developing a mathematical model that has been verified and validated by experimental tests on physical devices.

Journals

[1] De Carli A., Una formazione in Ingegneria collegata al mondo del Lavoro. *Editoriale per Automazione e Strumentazione*, 2007.

[2] De Carli A., Andreozzi S., Fiaschetti A., Documentazione dei requisiti di un sistema controllato. *Automazione e Strumentazione*, anno LV, n. 11, 2007, pag. 80-86.

[3] De Carli A., De Persis C., Modalità di controllo su reti wireless *Editoriale per Automazione e Strumentazione*, 2007.

[4] Gabriele S. and Di Giamberardino P., Dynamic sensor networks. *Sensors & Transducers Journal*, 81, pp. 1302–1314, 2007.

[5] Monaco S. , Normand-Cyrot D., Advanced tools for nonlinear sampled-data systems : Analysis and control. *European Journal of Control*, 13, pp. 221-241, 2007.

[6] Monaco S. , Normand-Cyrot D. and Califano C., From chronological calculus to exponential representations of continuous-time and discrete-time dynamics: a Lie algebraic approach *IEEE Transactions on Automatic Control*, 52, N.12, pp. 2227–2241, 2007.

Conference proceedings

[7] Barbot J.P., Monaco S. , Normand-Cyrot D., On the observer for differential-difference representations of discrete-time systems. In *European Control Conference, ECC'07*, KOS, July 2007.

[8] Califano C., Monaco S. and Normand-Cyrot D., State estimation for two output systems in Discrete Time. In *Proceedings of Nolcos*, August 2007.

[9] Dellino G., Lino P., Meloni C., Rizzo A., Di Giamberardino P. and Usai A., Modeling and simulation study for the design of controlled IPMC actuators. In *7th Meeting on Applied Scientific Computing and Tools (MASCOT07)*, Rome, Italy, September 2007.

[10] Gabriele S., Di Giamberardino P., Dynamic sensor networks: an approach to optimal dynamic field coverage. In *Proc. of the 4th Int. Conf. on Informatics in Control, Automation and Robotics*, Angers, France, May 2007.

[11] Gabriele S., Di Giamberardino P., Communication constraints for mobile sensors networks. In *Proc. 11th WSEAS Int. Conf. on Systems*, Crete, Greece, July 2007.

[12] Monaco S. and Normand-Cyrot D., Accessibility under multirate control for nilpotent lie algebra. In *Proceedings of the IEEE Conference on Decision and Control*, pp. 6262 - 6267, December 2007.

[13] Monaco S. and Normand-Cyrot D., On digital controller inversion. *SICPRO'07*. Mosca, January, 2007.

[14] Monaco S. and Normand-Cyrot D., Linearization by output injection under sampling. In *European Control Conference, ECC'07*. KOS, July, 2007.

[15] Usai A. and Di Giamberardino P., Homography-based mobile robot modeling for digital control implementation. In *Proc. of the 4th Int. Conf. on Informatics in Control, Automation and Robotics*, Angers, France, 2007.

Submitted papers, technical reports and others

[16] Battilotti S., Califano C., A geometric approach to dynamic feedback linearization. In *Analysis and design of nonlinear control systems*, pp. 397-411, A. Astolfi and L. Marconi Eds, Springer–Verlag, 2008.

[17] Baldesi G., Modelling, control design and simulation for a launch vehicle: from linear to nonlinear methods. Supervisors S. Monaco, C. Berard, Ph.D Thesis co-supervised for the simultaneous acquisition of the Italian and French Ph.D degrees, April 2008.

[18] Baldesi G., Monaco S., Bérard C. and Resta R.D., Modelling, simulation and validation of different control strategies. In *AIAA Atmospheric Flight Mechanics Conference and Exhibit*, accepted for publication, August 2008.

[19] Califano C., Monaco S. and Normand-Cyrot D., Observers with linear error dynamics for discrete time multi output systems. *Submitted to Automatica*, 2006.

[20] Fabbri F., Lassailly Y., Peretti J., Boilot J.-P., Lahlil K., Tard C. Controle Optique du Mouvement et de l'Organisation de Nanoparticules. Presented at *C'NANO IdF*, Ile De France, february 2008.

[21] Monaco S. , Normand-Cyrot D., Controller and observer normal forms in discrete-time. In *Analysis and design of nonlinear control systems*, pp. 377-396, A. Astolfi and L. Marconi Eds, Springer–Verlag, 2008.

[22] Monaco S. and Normand-Cyrot D., On input-state matching under multirate digital control. In *SICPRO'08*. Mosca, January, 2008.

[23] Saussie D., Baldesi G., Doll G. and Bérard C., Self Scheduling controller for a launcher in atmospheric ascent. In *IFAC*, accepted for publication July 2008.

Ph.D. thesis

[24] Usai A. Visual Feedback for Nonholonomic Mobile Robots: Modeling, Estimation, Control and Applications. Supervisor P. Di Giamberardino, Ph.D. Thesis, April 2007.

3.2.3 Identification and Optimal Control

The scientific interest of the group lies in two main areas: modeling, identification and filtering for discontinuous 2D signals and dynamical systems; deterministic and stochastic optimal control.
In the first area the problems of edges detection and non rigid motion estimation from a sequence of blurred and noisy images have been considered. Also the problem of statistical analysis of human retina pseudoimages has been studied.
In the second area the application of filtering and optimization tecniques to traffic control in a wireless communication network was considered (part of this latter research was developed in the framework of the IMAGES, EQoS and WEIRD projects belonging to the Information Society and Technology programme, sponsored by the 6th Framework EU programme).

Group members

Faculty members: Carlo BRUNI, Francesco DELLI PRISCOLI
PostDoc: Claudia FERRONE, Ilaria MARCHETTI
PhD student: Valentina RUSSO
Visitors: Norberto GRZYWACZ, Giorgio KOCH, Matteo LUCCHETTI, Caterina SCOGLIO.

Non rigid motion estimation and pixel selection from images time sequences These problems have received a great deal of attention due to their importance in many scientific fields (biomedicine, geophysics, communications, robotics, etc), and are indeed meaningful, since measured images are usually degraded by blurring effect and additive noise.
Degraded images time sequences have been considered, assuming that the represented objects can non rigidly move and in particular that motion and deformation law is described by an affine time dependent transformation on $\mathbf{R^2}$. The problem of motion estimation has been studied: this is a nonlinear problem and therfore suitable approximate filtering techniques are requested. In particular gaussian approximations by linearization methods have been considered. In order to reduce the computing complexity a suitable reduction of the number of pixels to be processed is a point of significant interest. A procedure has been proposed for an optimal selection, based on the evaluation of the additive information content for each pixel of the considered frame.

Modeling and Processing of Biomedical Systems The optical coherence tomography data from the human retina constitute pseudoimages with an informative content relevant for diagnostic purposes in many pathological diseases. A study has been developped in order to model the statistical properties of the above pseudoimages, either for sound or for pathological subjects. The aim of this study is to search for statistical procedures for automatic diagnosis of retinal pathologies.

Modeling, filtering and optimal control of communication networks The problem of congestion and admission control for a telecommunication network has been considered. As a first step the problem of modeling the network as a stochastic dynamical system has been tackled, with the aim of formulating an optimal control problem, transforming the quality of service requirements into suitable analytic constraints. A simplified formulation of the problem has been considered, characterized by the decomposition of the time control interval into a sequence of subintervals, thus dealing with a sequence of easy optimization problems. An on line procedure for the solution of the CAC problem has been given following this approach, characterized by the following qualifying points:
TECHNOLOGY INDEPENDENCE: the proposed procedure can be applied to any kind of wired or wireless communication network.
OPTIMALITY AND SYNTHETIZABILITY: the procedure maximizes a suitably defined performance index, while respecting the quality of service constraints, within all the feedback (robust) solutions.
STOCHASTIC DYNAMIC PERFORMANCE: the procedure accounts for past and foreseen future evolution of the network, described by a suitable dynamical model and tested by periodical time measurements.
COORDINATED AND COHERENT DECOUPLING: the procedure is compatible with the solution of the other simultaneous network management problems; in fact it works independently from them and, at the same time, it makes easier their solution.

Journals

[1] Bruni C., Delli Priscoli F., Koch G., Marchetti I., Discrete Time Optimal Solution for the Connection Admission Control Problem, *Int. J. of Computer Science and Engineering*,**1**, 1, 2007.

[2] Bruni C., Ferrone C., Koch G., Lucchetti M., Non rigid Motion Estimation from a Sequence of Degraded Images, *Mathematical and Computer Modelling*, **47**, 3/4, 2007.

Conference proceedings

[3] Bruni C., Delli Priscoli F., Koch G. Marchetti I., The Connection Admission Problem in Internet Networks: an Optimal Control Approach, *proc. European Control Conference 2007*, Kos (Greece), July 2007.

[4] Bruni C., Ferrone C., Koch G., Lucchetti M., Pixel selection in Motion Estimation Problem from a Sequence of Degraded Images, *proc. 4th Int. Conference on Cybernetics and Information Technologies, Systems and Applications*, Orlando (Florida), July 2007.

Submitted papers, technical reports and others

[5] Bruni C., Delli Priscoli F., Koch G. Marchetti I., Resource Management in Network Dynamics: an Optimal Approach to the Admission Control Problem, submitted.

[6] Bruni C., Ferrone C., Koch G., Lucchetti M., Motion Identification from Image Sequences: Information Theory and Pixel Selection, *Computer and Mathematics with Applications*, to appear.

[7] Grzywacz N., De Juan J., Ferrone C., Giannini D., Huang D., Koch G., Russo V., Tan O. and Bruni C., Statistics of Optical Coherence Tomography Data from Human Retina, submitted.

3.2.4 Nonlinear Systems

The research group in Nonlinear Systems is involved in the development of the following topics: control under communication constraints, control over memoryless channels, dynamic feedback linearization, network control and handling, nonlinear control applications, nonlinear regulation, quantized control, stabilization of nonlinear systems.

Claudio De Persis participates in *Plug & Play Process Control*, a five-year Research Program supported by The Danish Research Council for Technology and Production Sciences. He is also a member of the HYCON IAC-CNR research unit.

Francesco Delli Priscoli is the scientific responsible of four research projects funded by the European Union (EU) (DAIDALOS II, EuQoS, IMAGES, WEIRD and SATSIX) and two research projects funded by the Italian University and Research Ministry (MIUR) (M3CAST and APICE), entailing a net financing for the year 2007 of about 700.000 Euro. These projects, performed within consortia involving major european universities and research centers, manufactures and operators, aim at the research, the design, the development, the interoperation and the standardisation of advanced wireless and wired networks (UMTS, WiMax, IPv6 satellites, DVB H, x-DSL). These research projects have been carried on by combining competences and methodologies relevant to control, information, operations research and telecommunications, thanks to the cooperation of Professors, Researchers and PhD Students of DIS and also of INFOCOM departments. In 2007, work contracts have been granted on these activities to 20 young engineers and about 40 PhD and Master theses have been discussed on these issues.

Group members

Faculty members Stefano BATTILOTTI, Fabio CELANI, Francesco DELLI PRISCOLI, Claudio DE PERSIS, Alberto ISIDORI.
Post-Docs Tiziano INZERILLI, Ilaria MARCHETTI, Antonio PIETRABISSA, Gianfranco SANTORO, Gabriele TAMEA.
PhD students Marco CASTRUCCI, Alessandro DI GIORGIO, Andrea MERCURIO, Silvano MIGNANTI, Fabio MITRANO, Laura PIMPINELLA, Filippo RODRIGUEZ, Vincenzo SURACI, Marco VEROLI.

Control under Communication Constraints Control systems with a communication channel in the feedback loop can be conveniently modeled as hybrid (impulsive) systems. For the class of nonlinear systems in feedfoward form, we design in [19, 20, 8] a hybrid controller which guarantees asymptotic stability, in spite of the quantization noise and of an arbitrarily large delay which affects the channel. The rate at which feedback packets are transmitted from the sensors to the actuators is shown to be arbitrarily close to the infimal one. To ease the computational burden of the approach, in [24] we introduce a new class of dynamic encoders for continuous-time nonlinear control systems which update their parameters only at discrete times. We prove that the information reconstructed from the encoded feedback can be used to deliver a piece-wise constant control law which yields semi-global practical stability. The problem of controlling a general class of nonlinear systems through a memoryless channel with constant delay has been studied [12]. The remote controller receives the delayed measurements from the controlled plant and transmits back to the plant a control law, designed according to a certainty equivalence strategy. The closed-loop system trajectories are convergent to zero in probability and square integrable, despite the presence of uncertainties and square integrable noise.

Control over Memoryless Channels The problem of controlling a general class of nonlinear systems through a memoryless channel with time-delay and additive noise has been studied [12]. The remote controller receives the delayed measurements from the controlled plant and transmits

back to the plant a control law, designed according to a certainty equivalence strategy. The closed-loop system trajectories are convergent to zero in probability and square integrable.

Dynamic Feedback Linearization In [13] we deal with dynamic feedback linearization of multi input continuous time affine systems. The geometric properties of a dynamic feedback linearizable system as well as those of the compensator which achieves linearization are here enlightened. On the basis of these geometric properties an algorithm for the computation of a dynamic feedback obtained from the composition of regular static state feedback laws and integrators is proposed.

Network Control and Handling This research has been mainly performed in the framework of the EU research projects DAIDALOS II, EuQoS, IMAGES, WEIRD, SATSIX, and the MIUR research projects M3CAST and APICE. DIS role concerned the research, design, simulation (NS-2, OPNET, Matlab) and implementation (Linux, Java, C++) of procedures relevant to the topics listed below.

QoS and Resource Management procedures. The key provided added value is the innovative approach which combines telecommunication with control-based methodologies. In particular, we applied robust control, predictive control, bound optimization, game theory to deal with Connection Admission Control, Routing, Congestion Control, Dynamic Bandwidth Management, Packet Scheduling procedures, for both wireless (Wi-Fi, UMTS, Wi-Max, DVB-H, ad hoc networks, satellites...) and wired systems.

Interoperability Management. We designed, simulated and implemented architectures which allow the decoupling of the QoS, Mobility and Security procedures from the specific underlying technologies. In this way, these procedures can be designed with an abstract technology-independent approach, which allows to exploit control-theoretic methodologies to achieve robustness with respect to underlying network evolutions.

Service Management. We performed many implementations related to Service Discovery, Filtering, Composition, Selection and Ranking to provide users with personalized, context- and location-aware services even offered by different heterogeneous networks.

Finally, we performed other researches and implementations on *Multicast/Broadcast Control* and *Content Adaptation Control*.

These researches are reported in several papers published on major international conferences and reviews ([2], [7], [9], [14], [17], [18], [25], [28], [31], [32], [33], [34], [35]), as well as in a plenty of project deliverables.

Nonlinear Control Applications A number of real-life control applications have been developed in close collaboration with industrial partners. In [23], the problem of regulating to a reference value the pressure drop across the components of a large-scale nonlinear hydraulic network has been formulated. The control goal is achieved employing a set of distributed proportional and proportional-integral controllers fed by local feedback information only. Experimental validation of the results is in progress. In [22], we examine a distributed control problem for internal flow management in a multi-zone climate unit. The problem consists of guaranteeing prescribed climate conditions in a cascade connection of an arbitrarily large number of communicating zones. We devise control laws which yield hybrid closed-loop systems, depend on local feedback information, take on values in a finite discrete set, and cooperate with neighbor controllers to achieve different compatible control objectives, while avoiding conflicts.

Nonlinear Regulation Research in this area has been addressed to various problems of nonlinear output regulation.

Paper [5] addresses the problem of the existence of an (output) feedback law that asymptotically steers to zero prescribed outputs, while keeping all state variables bounded, for any initial conditions in a given compact set.

The goal of papers [15] and [6] is to provide a reduction paradigm for the design of output regulators which can be of interest for nonlinear as well as linear uncertain systems. The main motivation of the work is to provide a systematic design tool to deal with non-minimum-phase uncertain systems for which conventional high-gain stabilization methods are not effective.

Paper [30] provides a tutorial presentation of a number of recent advances in nonlinear output regulation.

In paper [29] we investigate the concept of steady state response for nonlinear systems. As an application, we show how the concept in question plays a role of paramount importance in the design of control laws for asymptotic tracking and disturbance attenuation.

In paper [26] it is shown how the availability of supplementary measurement outputs, in addition to the regulated variable, can be exploited to the purpose of overcoming certain current design limitations, extending the analysis to classes of systems with a possibly unstable zero dynamics.

The contribution of paper [16] consists in showing that, when the regulated error is unmeasurable, a design based on certainty equivalence is effective for determining a controller that achieves semiglobal output regulation.

Quantized Control By quantized control it is meant a piece-wise constant control law taking values in a finite set. In [3], we have shown that a Lyapunov redesign of the control law allows us to semi-globally practically stabilize by quantized control any nonlinear stabilizable system. In [21], the same problem is considered in the case of *uncertain* systems. The basic tool is a discontinuous version of the so-called semi-global backstepping lemma. We derive robust practical stabilizability results by quantized controllers and apply them to some significant control problems.

Stabilization of Nonlinear Systems In [1] we study the problem of rendering integral input to state stable with respect to noise a general class of upper triangular nonlinear systems with uncertainty and measurement noise. We propose a novel step-by-step Lyapunov-based design, consisting of 1) splitting a n-dimensional system into n one-dimensional systems, each with its own state, inputs and measurement, 2) constructing a one-dimensional measurement feedback controller for each one-dimensional system, according to a certainty equivalence principle, and 3) selecting the parameters of these controllers so that their interconnection gives a measurement feedback controller for the n-dimensional system. The stability analysis is performed through filtered Lyapunov functions, which are Lyapunov functions with parameters being the output of suitable dynamical filters.

In [11] we introduce a new type of Lyapunov functions in a general framework particularly suitable for the analysis of systems with noise and uncertainty. These Lyapunov functions may depend on parameters possibly satisfying differential equations or inequalities. The main differences with respect to classical Lyapunov functions and classical tools for the design of composite Lyapunov functions are discussed through examples. A design tool for the design of composite filtered Lyapunov functions is given, and examples show improvements over existing literature.

Journals

[1] Battilotti S. Lyapunov-based design of iISS feedforward systems with uncertainty and noisy measurements, *SIAM Journal on Control and Optimization*, 46, 84-115, 2007.

[2] Bruni C., Delli Priscoli F., Koch G., Marchetti I. Discrete Time Optimal Solution for the Connection Admission Control Problem. *Int. J. of Computer Science and Engineering*, 1(1), 1-9, 2007.

[3] Ceragioli F., De Persis C. Discontinuous control of nonlinear systems: Quantized and switched controls. *Systems & Control Letters*, Vol 56, 7-8, 461-473, 2007.

[4] Kim J.-S., Yoon T.-W., De Persis C. Discrete-time supervisory control of input-constrained neutrally stable linear systems via state-dependent dwell-time switching. *Systems & Control Letters*, Vol 56, 7-8, 484-492, 2007

[5] Marconi L. , Praly L., Isidori A. Output stabilization via nonlinear Luenberger observers, *SIAM Journal on Control and Optimization*, 45, 2277-2298, 2007.

Conference proceedings

[6] Celani F., Isidori A., Marconi L. A reduction paradigm for output regulation. In *Proceedings of the European Control Conference 2007.* Kos, Greece, July, 2007.

[7] Bruni C., Delli Priscoli F., Koch G., Marchetti I. The Connection Admission Problem in Internet Networks: an Optimal Control Approach. In *Proceedings of the European Control Conference 2007.* Kos, Greece, 1185-1191, 2007.

[8] De Persis C. Minimal data rate stabilization of nonlinear systems over networks with large delays. In *Proc. of ConCom07*, Limassol, Cipro, April 20, 2007.

[9] Delli Priscoli F., Pietrabissa A. Proposals and evaluation of network routing metrics. In *Proceedings of the European Control Conference 2007.* Kos, Greece, 2007.

[10] Delli Priscoli F., Isidori A., Marconi L. Output regulation: A geometric viewpoint. In *Proceeding of the NOLCOS Conference*, 2007.

Submitted papers, technical reports and others

[11] Battilotti S., Filtered Lyapunov Functions and their Applications in the Stability Analysis of Nonlinear Systems, to appear in *IEEE Transactions on Automatic Control*, 2008.

[12] Battilotti S., Control over a communication channel with random noise and delays, to appear in *Automatica*, 2008.

[13] Battilotti S., Califano C., A geometric approach to dynamic feedback linearization. In *Analysis and design of nonlinear control systems*, pp. 397-411, A. Astolfi and L. Marconi Eds, Springer–Verlag, 2008.

[14] Bruni C., Delli Priscoli F., Koch G., Marchetti I. Resource Management in Network Dynamics: an Optimal Approach to the Admission Control Problem, submitted to *Control Engineering Practice*, December 2007.

[15] Celani F., Isidori A., Marconi L. A reduction paradigm for output regulation, to appear in *International Journal of Robust and Nonlinear Control,* 2008.

[16] Celani F. Certainty equivalence in nonlinear output regulation with unmeasurable regulated error, to appear in *Proceedings of the 17th IFAC World Congress,* Seoul, South Korea, July, 2008.

[17] Conforto P., Delli Priscoli F., Facchinei F. A non-cooperative game for QoS routing: Properties of the Nash equilibrium point, submitted to *Control Theory and Applications*, 2007.

[18] Conforto P., Delli Priscoli F. Game theoretic model and distributed admission control for an innovative distributed QoS routing, submitted to *Control Engineering Practice*, 2007.

[19] De Persis C. Hybrid feedback stabilization of nonlinear systems with quantization and large delays. In *Analysis and Design of Nonlinear Control Systems. In Honor of Alberto Isidori*. A. Astolfi, L. Marconi eds., Springer Verlag, 465–483, 2008.

[20] De Persis C. Minimal data rate control of nonlinear systems over networks with large delay. arXiv:0706.2631v2.

[21] De Persis C. Robust stabilization of nonlinear systems by quantized and ternary control. In *Proc. 17th IFAC World Congress*, Seoul, Korea, July 6-11, 2008.

[22] De Persis C., Jessen J.J., Izadi-Zamanabadi R., Schioler H. A distributed algorithm for internal flow management in a multi-zone climate control unit. *International Journal of Control*, 81, 1, 89–106, 2008.

[23] De Persis C., Kallesoe C.S. Proportional and proportional-integral controllers for a nonlinear hydraulic network. In *Proc. 17th IFAC World Congress*, Seoul, Korea, July 6-11, 2008.

[24] De Persis C. and Nešić D. Practical encoders for controlling nonlinear systems under communication constraints. *Systems & Control Letters*, **57**, 8, 654-662, 2008.

[25] Delli Priscoli F., Dini P. A Quality of Service Support Module (QASM) for a Wireless Multi-Segment Integrated 3G Network, to appear in *Wireless Personal Communications (WIRE)*, 2007.

[26] Delli Priscoli F., Isidori A., Marconi L. Output regulation with redundant measurements, to appear in *Journal of Control, Measurement and Systems Integration*, 1, 1-10, 2008.

[27] Delli Priscoli F, Pietrabissa A. Paving the Way towards the Control of Wireless Telecommunication NetworksIn *Analysis and Design of Nonlinear Control Systems. In Honor of Alberto Isidori*. A. Astolfi, L. Marconi eds., Springer Verlag, 465-483, 2008.

[28] Delli Priscoli F., Pompili D. A Demand Assignment Algorithm based on a Markov Modulated Chain Prediction Model for Satellite Bandwidth Allocation, to appear in *Wireless Networks*, 2007.

[29] Isidori A., Byrnes C.I. Steady-state behaviors in nonlinear systems with an application to robust disturbance rejection, to appear in *Annual Reviews in Control*, 2008.

[30] Isidori A., Marconi L. System regulation and design: geometric and algebraic methods, to appear in *Encyclopedia of Complexity and Systems Science*, Springer Verlag, 2008.

[31] Pietrabissa A. A New LP Formulation of the Admission Control Problem under Average Reward", submitted to *Discrete Event Dynamic Systems*, 2007.

[32] Pietrabissa A. A policy approximation method for the UMTS connection admission control problem modeled as a MDP, submitted to *International Journal of control*, 2007.

[33] Pietrabissa A. Admission Control in UMTS Networks based on Approximate Dynamic Programming, to appear in *European Journal of Control*, Vol. 14, N. 1, 2008.

[34] Pietrabissa A. An Adaptive Multi-Model Reference Control Approach for Bandwidth-on-Demand in Satellite Networks, to appear in *Control Engineering Practice*, Vol. 16, Issue 7, 2008, pp. 847-860, DOI information: 10.1016/j.conengprac.2007.10.001.

[35] Pietrabissa A. An Alternative LP Formulation of the Admission Control Problem in Multi-Class Networks, to appear in *IEEE Transaction on Automatic Control*, Vol. 53, N. 3, 2008.

3.2.5 Robotics

Robotics research at DIS is committed to the development and experimental validation of planning and control techniques for manipulators and mobile robots.
Active grants include the EU projects *CyberWalk* and *PHRIENDS*, both STREP-IST within FP-6. In 2007, we have cooperated with the following foreign institutions: the *DLR Institute for Robotics and Mechatronics* in Wessling (Germany), the *Technische Universität München* in München (Germany), the *Max Planck Institute for Biological Cybernetics* in Tübingen (Germany), and the *Department of Computer Science–University of Illinois* in Urbana (USA), the *IRISA/INRIA* in Rennes (France). At the national level, we have collaborations with *Campus Biomedico* and *Fondazione Santa Lucia IRCCS* in Roma, *DII–Università di Siena*, *DIS–Università di Napoli Federico II*, *DAEIMI–Università di Cassino*, *Centro "E. Piaggio"–Università di Pisa*, and *DEIS–Università di Bologna*.
Members of this group have organized the *2007 IEEE International Conference on Robotics and Automation*, which was held in Roma, April 10–14, 2007: A. De Luca (General Chair), G. Oriolo (Organization Chair), M. Vendittelli (Registration Chair).

Group members.

Faculty members: Alessandro DE LUCA, Leonardo LANARI, Giuseppe ORIOLO, Marilena VENDITTELLI.
Post-Docs: Luigi FREDA, Raffaella MATTONE.
PhD students: Andrea CHERUBINI, Antonio FRANCHI, Luca MARCHIONNI, Paolo ROBUFFO GIORDANO.

Robots with Elastic Joints Joint elasticity is the main source of vibration in industrial robots, with harmonic drives, belts, or long shafts as transmission elements. An overview on modeling and control techniques for robots with joint elasticity is given in a chapter of the Springer *Handbook of Robotics* [33], the largest editorial effort in our field.
An observer of the full robot state (position and velocity on motors and links) based only on motor position sensing and on link accelerometers has been introduced in [13], and the resulting observer-based control validated on a *KUKA KR15/2* industrial robot.
Friction is a critical issue in any robotic system. A disturbance observer and an associated stable control law have been proposed for friction compensation on the motor side of elastic joint robots [40], without using an explicit friction model. The method has been successfully implemented on a 7-dof arm for medical applications.
Novel actuation/transmission devices with on-line variable stiffness have been recently developed for safe physical human-robot interaction. Simultaneous and decoupled control of both link motion and joint elasticity of multi-dof robots equipped with such devices can be obtained by means of either static or dynamic feedback linearization [41].

Robots with Flexible Links Lightweight manipulators with very slender mechanical design usually imply the presence of vibrations due to distributed link flexibility. For regulation tasks, a PD control law with on-line gravity compensation has been proposed in [20]. Global asymptotic stabilization is obtained using only measurements at the robot joints and not of the link deflection. For a single flexible link, we improved our previous results on planning a rest-to-rest motion in given time and without residual oscillations. Based on the definition of a suitable output, a smoothed bang-bang torque profile can be designed that uses at best the bounded actuator capabilities [31].

Redundant Manipulators A robot is kinematically redundant with respect to a task when the number of its degrees of freedom is larger than the number of task variables. An overview of

kinematic/dynamic planning and control techniques for redundant manipulators is presented in a chapter of the Springer *Handbook of Robotics* [28].
Redundancy has been used in [32] for preserving the execution of end-effector trajectories, despite the occurrence of a physical collision along the robot structure. Robot reaction to collision (see also the section on Human-Robot Interaction) is projected into a dynamic null-space, thus not affecting the original end-effector task whenever possible.

Nonholonomic Systems Robotic systems subject to nonholonomic constraints (e.g., due to rolling contact of wheels or balls) pose challenges in motion planning and control tasks.
An analytical method has been presented for computing the distance between a Dubin's car (a robot moving only forward) and polygonal obtacles, based on Pontryagin's Maximum Principle and taking into account nonholonomic constraints and non-symmetric nature of the system [44].
A closed-form solution to the simultaneous calibration of the odometry and of a range sensor mounted on a differential-drive wheeled mobile robot has been given using a maximum-likelihood approach [24]. The method does not require specific motion trajectories and has been tested on a *Khepera III* robot with HOKUYO laser rangefinder.
For the ball-bearing nonholonomic platform *CyberCarpet*, intended for 'natural walking' in VR, we have extended at the acceleration level our previous motion control design using backstepping and cascaded control [14].

Visual Servoing Visual servoing (VS) is a very active research area in robotics. In particular, in the image-based (IB) VS framework, error signals are directly computed from image features, thus obtaining control schemes which do not need a 3D model of the scene and are more robust to calibration errors.
In [2], we have presented a two-level IBVS scheme for intercepting a moving target (a ball) with a nonholonomic mobile robot carrying a pan-tilt camera. For the case of nonholonomic mobile manipulators, we have introduced in [1] a compact framework for formulating and solving VS tasks via IB control. In [30], a general approach for redundancy exploitation in IBVS tasks has been proposed and experimentally evaluated.
The on-line estimation of the unknown depth of visual point features, and the integration of such information in IBVS schemes, are the subject of [15, 22, 34]. The same technique, which is based on nonlinear observation theory, has been extended to non-point features (image moments) in [42]. Also, depth estimation has been used as a component of a VS scheme for assembling complex planar parts in [43].
For wheeled nonholonomic mobile robots equipped with an on-board camera, an IB posture regulation method based on epipolar geometry has been proposed [3]. For the same type of robot, we have also considered the path following problem; both position-based and image-based schemes have been devised, which use only a small set of features extracted from the image plane. The performance of the controllers has been theoretically analyzed and experimentally verified in [21, 25, 26].

Motion Planning Modelling robot motion planning with uncertainty in a Bayesian framework leads to a computationally intractable stochastic control problem. In [23], we show how to reduce the stochastic control problem to path-planning in the extended space of poses and covariances; the transitions between states are modeled through the use of Fishers information matrix. In this framework, two problems are considered and solved: minimizing the execution time, and minimizing the final covariance with an upper bound on the execution time.

Sensor-based Planning and Exploration The task of exploring unknown environments typically requires a robot to use the information provided by its sensory system to cover an unknown area while learning a model of the environment. A simple and effective idea is that the robot should always move towards the boundary between already explored and still unknown areas while maximizing the motion expected utility. Building on this idea, we have proposed both decentralized exploration strategies for teams of mobile robots [16, 17, 36] and methods for exploration with robot manipulators [37] .
Strictly related with the exploration is the problem of determining the minimal sensor requirements for navigation and environment model representation, which is investigated in [18] and [19].

Human-Robot Interaction Safety issues in the physical human-robot interaction have to be addressed at the mechanical and control levels. A survey on the status of technologies and methodologies for safe human-robot interaction has been presented in [35].
We have further developed our fast and reliable method for detection and reaction to unexpected collisions. Several post-impact reaction strategies were compared in terms of sensitivity, response times, and associated energy transfer, with collision experiments between the *KUKA/DLR* lightweight manipulator and a crash-test dummy, as well as human chest, arm, and head [38]. The safety of the approach has been evaluated also when the robot is equipped with sharp tools and hits on soft biological tissues [39].
A new aspect of cognitive human interaction is to allow unconstrained locomotion for a user exploring virtual worlds while walking on a platform. For a linear threadmill, we have developed control laws (including an observer of the user's intentional motion) for keeping the user at the platform center and limiting the perceptual effects due to threadmill motion [45]. The method is now being applied to an omnidirectional platform.

Service Robotics Assistive technology is an emerging area where robotic devices can be used to strengthen the limited abilities of individuals with motor impairment or to help them achieve independence in the activities of daily living. In [12, 29] we present a project (funded by the Italian *Telethon Foundation* and in collaboration with *Fondazione Santa Lucia*) aimed at developing a system that provides remote control of home-installed appliances, including robotic devices such as the Sony *AIBO*. The design of the robot navigation system is described in [8, 27]. Single step, semi-autonomous, and autonomous operating modes have been realized to provide different levels of interaction with the *AIBO*. In particular, the autonomous navigation mode relies on a vision-based path planning/following module described in [9]. The performance of the navigation system has been tested in simulation as well as experiments. Also, the system underwent clinical validation, in order to obtain a definitive assessment through patient feedback.
Another area of activity of our group are robotic games. In [10], a layered approach is presented for learning optimal parameters of basic control routines and behaviours for a quadruped robot (the *AIBO*) used in a soccer competition (the *RoboCup*). The same application is considered in [11], where an extended policy gradient algorithm is proposed for concurrent learning of the best ball attack strategy.

Hierarchical Control Analysis and control of large scale systems can be tackled introducing of a hierarchy in the system, i.e., the definition of a high-level model bare of modeling details for which reduced-order control design is easier. The resulting high-level control law must be then 'translated' for execution on the original, low-level system. In [5] and [7], a unified geometric framework underlying most of the existing methodologies has been presented highlighting the role of subspaces invariance. Some limitations of the resulting invariance-based approaches have

been investigated in [6], together with possible extensions. Finally, a hierarchical approach to trajectory tracking has been illustrated in [4] with connections to a simulation-based approach.

Journals

[1] De Luca A., Oriolo G., and Robuffo Giordano P., Image-based visual servoing schemes for nonholonomic mobile manipulators. *Robotica* (Special Issue on Mobile Manipulators: Basic Techniques, New Trends & Applications), 25(2):131–145, 2007.

[2] Freda L. and Oriolo G., Vision-based interception of a moving target with a nonholonomic mobile robot. *Robotics and Autonomous Systems*, 55(6):419–432, 2007.

[3] Mariottini G. L., Oriolo G., and Prattichizzo D., Image-based visual servoing for nonholonomic mobile robots using epipolar geometry. *IEEE Transactions on Robotics*, 23(1):87–100, 2007.

Conference proceedings

[4] Cavarischia L. and Lanari L., Hierarchical tracking implementation. *Proc. of 46th IEEE Conf. on Decision and Control*, pp. 3733–3738, New Orleans, LA, USA, 2007.

[5] Cavarischia L. and Lanari L., Subspaces invariance constraints in large scale systems. *Proc. of 15th Med. Conf. on Control and Automation*, Athens, GR, 2007.

[6] Cavarischia L. and Lanari L., Hierarchical control implementation. *Proc. of 15th Med. Conf. on Control and Automation*, Athens, GR, 2007.

[7] Cavarischia L. and Lanari L., Invariant subspaces in large scale systems. *Proc. of 11th IFAC/IFORS/IMACS/IFIP Symp. on Large Scale Systems*, Gdansk, PL, 2007.

[8] Cherubini A., Oriolo G., Macrì F., Aloise F., Babiloni F., Cincotti F., and Mattia D., Development of a multimode navigation system for an assistive robotics project. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, pp. 2336–2342, Roma, I, 2007.

[9] Cherubini A., Oriolo G., Macrì F., Aloise F., Cincotti F., and Mattia D., A vision-based path planner/follower for an assistive robotics project. *Proc. of 1st Int. Work. on Robot Vision*, pp. 77–86, Barcelona, E, 2007.

[10] Cherubini A., Giannone F., and Iocchi L., Layered learning for a soccer legged robot helped with a 3D simulator. *Proc. of 11th Robocup Int. Symp.*, Atlanta, GA, USA, 2007.

[11] Cherubini A., Giannone F., Iocchi L., and Palamara P. F., An extended policy gradient algorithm for robot task learning. *Proc. of IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, IROS 2007*, pp. 4121–4126, San Diego, CA, USA, 2007.

[12] Cincotti F., Aloise F., Bufalari S., Schalk G., Oriolo G., Cherubini A., Davide F., Babiloni F., Marciani M. G., and Mattia D., Non-invasive Brain-Computer Interface system to operate assistive devices. *Proc. of 29th Int. Conf. of the IEEE Engineering in Medicine and Biology Society*, pp. 2532–2535, Lyon, F, 2007.

[13] De Luca A., Schröder D., and Thümmel M., An acceleration-based state observer for robot manipulators with elastic joints. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, pp. 3817–3823, Roma, I, 2007.

[14] De Luca A., Mattone R., and Robuffo Giordano P., Acceleration-level control of the CyberCarpet. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, pp. 2330–2335, Roma, I, 2007.

[15] De Luca A., Oriolo G., and Robuffo Giordano P., On-line estimation of feature depth for image-based visual servoing schemes. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, pp. 2823–2828, Roma, I, 2007.

[16] Franchi A., Freda L., Oriolo G., and Vendittelli M., A randomized strategy for cooperative robot exploration. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, pp. 768–774, Roma, I, 2007.

[17] Franchi A., Freda L., Oriolo G., and Vendittelli M., A decentralized strategy for cooperative robot exploration. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, Athens, G, 2007.

[18] Freda L., Trovar B., and LaValle S. M., Learning combinatorial information from alignments of landmarks. *Proc. of 2007 IEEE Int. Conf. on Robotics and Automation*, pp. 4295–4300, Roma, I, 2007.

[19] Tovar B., Freda L., and LaValle S. M., Using a robot to learn geometric information from permutations of landmarks. *Contemporary Mathematics*, American Mathematical Society, 438:33–45, 2007.

[20] Zollo L., Siciliano B., De Luca A., and Guglielmelli E., PD control with on-line gravity compensation for robots with flexible links. *Proc. of 2007 European Control Conf.*, pp. 4365–4370, Kos, GR, 2007.

Ph.D. thesis

[21] Cherubini A., *Vision-based techniques for following paths with mobile robots*. Ph.D. Thesis, Sapienza Università di Roma, 2007.

[22] Robuffo Giordano P., *Visual estimation and control of robot manipulating systems*. Ph.D. Thesis, Sapienza Università di Roma, 2007.

Submitted papers, technical reports and others

[23] Censi A., Calisi D., De Luca A., and Oriolo G., A Bayesian framework for optimal motion planning with uncertainty. Accepted for presentation at *2008 IEEE Int. Conf. on Robotics and Automation*, Pasadena, CA, USA, May 2008.

[24] Censi A., Marchionni L., and Oriolo G., Simultaneous maximum-likelihood calibration of robot and sensor parameters. Accepted for presentation at *2008 IEEE Int. Conf. on Robotics and Automation*, Pasadena, CA, USA, May 2008.

[25] Cherubini A., Chaumette F., and Oriolo G., Position-based and image-based visual servoing for following paths with nonholonomic mobile robots. Submitted for publication in *IEEE Transactions on Robotics*, 2008.

[26] Cherubini A., Chaumette F., and Oriolo G., A position-based visual servoing scheme for following paths with nonholonomic mobile robots. Submitted for presentation at *2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, Nice, F, September 2008.

[27] Cherubini A., Oriolo G., Macrì F., Aloise F., Cincotti F., and Mattia D., Development of a multimode navigation system for an assistive robotics project. Submitted for publication in *Autonomous Robots*, 2008.

[28] Chiaverini S., Oriolo G., and Walker I., Chapter 11: Kinematically redundant manipulators, in B. Siciliano, O. Khatib (Eds.) *Springer Handbook of Robotics*, Springer, to appear in 2008.

[29] Cincotti F., Mattia D., Aloise F., Bufalari S., Schalk G., Oriolo G., Cherubini A., Marciani M. G., and Babiloni F., Non-invasive Brain-Computer Interface system: Towards its application as assistive technology. Accepted for publication in *Brain Research Bulletin*, 2008.

[30] De Luca A., Ferri M., Oriolo G., and Robuffo Giordano P., Visual servoing with exploitation of redundancy: An experimental study. Accepted for presentation at *2008 IEEE Int. Conf. on Robotics and Automation*, Pasadena, CA, USA, May 2008.

[31] De Luca A. and Panzer H., Rest-to-rest motion of a one-link flexible arm with smooth bang-bang torque profile, Submitted for presentation at *9th Int. Conf. on Motion and Vibration Control*, München, D, September 2008.

[32] De Luca A. and Ferrajoli L., Exploiting robot redundancy in collision detection and reaction. Submitted for presentation at *2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, Nice, F, September 2008.

[33] De Luca A. and Book W., Chapter 13: Robots with flexible elements, in B. Siciliano, O. Khatib (Eds.) *Springer Handbook of Robotics*, Springer, to appear in 2008.

[34] De Luca A., Oriolo G., and Robuffo Giordano P., Feature depth observation for image-based visual servoing: Theory and experiments. Accepted for publication in *The International Journal of Robotics Research*, 2008.

[35] De Santis A., Siciliano B., De Luca A., and Bicchi A., An atlas of physical human-robot interaction. *Mechanism and Machine Theory*, 43(3):253–270, 2008.

[36] Franchi A., Freda L., Marchionni L., Oriolo G., and Vendittelli M., Decentralized cooperative exploration: Implementation and experiments. Submitted for presentation at *10th Int. Conf. on Intelligent Autonomous Systems*, Baden-Baden, D, July 2008.

[37] Freda L., Oriolo G., and Vecchioli F., Sensor-based exploration with robot manipulators. Submitted for presentation at *2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, Nice, F, September 2008.

[38] Haddadin S., Albu-Schäffer A., De Luca A., and Hirzinger G., Collision detection and reaction: A contribution to safe physical human-robot interaction. Submitted for presentation at *2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, Nice, F, September 2008.

[39] Haddadin S., Albu-Schäffer A., De Luca A., and Hirzinger G., Evaluation of collision detection and reaction for a human-friendly robot on biological tissues. Submitted for presentation at *6th IARP/IEEE/EURON Work. on Technical Challenges for Dependable Robots in Human Environments*, Pasadena, CA, USA, May 2008.

[40] Le Tien L., Albu-Schäffer A., De Luca A., and Hirzinger G., Friction observer and compensation for control of robots with joint torque measurements. Submitted for presentation at *2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, Nice, F, September 2008.

[41] Palli G., Melchiorri C., and De Luca A., On the feedback linearization of robots with variable stiffness. Accepted for presentation at *2008 IEEE Int. Conf. on Intelligent Autonomous Systems*, Pasadena, CA, USA, May 2008.

[42] Robuffo Giordano P., De Luca A., and Oriolo G., 3D structure identification from image moments. Accepted for presentation at *2008 IEEE Int. Conf. on Robotics and Automation*, Pasadena, CA, USA, May 2008.

[43] Robuffo Giordano P., Stemmer A., Arbter K., and Albu-Schäffer A., Robotic assembly of complex planar parts: An experimental evaluation. Submitted for presentation at *2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, Nice, F, September 2008.

[44] Robuffo Giordano P. and Vendittelli M., Time-optimal collision trajectories for the Dubins car. Submitted for publication in *IEEE Transactions on Robotics*, 2008.

[45] Souman J., Robuffo Giordano P., Frissen I., De Luca A., and Ernst M., Making virtual walking real: Perceptual evaluation of a new treadmill control algorithm. Submitted for publication in *ACM Transactions on Applied Perception*, 2008.

3.3 Management Science

3.3.1 Combinatorial Optimization

The research activity of the Combinatorial Optimization Group is mostly devoted to theoretical and computational aspects related to i) design of telecommunication networks and ii) job-shop scheduling problems.

The group is currently cooperating with Maastrich University, Konrad Zuse Zentrum fr Informationstechnik Berlin, Università di Roma Tor Vergata, Università dell'Aquila, Università di Lecce, Politecnico di Milano, and Fondazione Ugo Bordoni. It is currently involved in several national and international research project, including the MIPAF project ADM (Agricultural Data Mining), the MIUR projects M3-CAST and APICE (both devoted to Wireless Network Planning).

Faculty members Carlo MANNINO, Antonio SASSANO.
Post-docs Silvia CANALE, Sara MATTIA.
PhD students Fabio D'ANDREAGIOVANNI.

Network design and location *The P-Median problem* ([2]). The p-Median is a fundamental location problem. It consists of determining p nodes (the median nodes) minimizing the total distance from the other nodes of the graph. Its relevance stems from the relationship with the stable set problem and from its crucial role as a basic building block of more complex location problems.

Wireless Network Optimization and Planning ([1, 6, 13, 10, 1]). Radio and television broadcasting, cellular mobile telecommunication systems, satellite-based cellular networks and many other important civil and military applications require a huge number of antennas to be located on the territory so as to maximize the coverage or some kind of measure of the service.

Network loading ([3]). The problem of designing good quality and low cost networks arises in several real-life applications like transportation and telecommunication ones.

Job-shop Scheduling Problems ([11]). These problems were studied in the context of train scheduling and routing.

Computational Molecular Biology, Peptide Sequencing ([9, 8]). Several computationally demanding problems arise from biological and medical research. In particular, Sequencing problems are of great relevance in several applicative fields. Data obtained from the mass spectrometry analysis of a generic compound, constituted, according to specific chemical rules, by an unknown sequence of components, should be processed in order to determine such sequence.

Satisfiability ([7]). Propositional satisfiability (SAT) is a central problem in many different fields, e.g. Artificial Intelligence, Cryptography, Database Systems, logic circuit design and testing.

Data Mining, Classification and Universe selection ([5]) Data Mining is in general the process of extracting useful infomation from large amount of data. In particular, relevant data mining tasks are, among others, Classification and Universe Selection.

Journals

[1] Aardal K., van Hoesel S.P.M., Koster A., Mannino C., and Sassano A., Models and Solution Techniques for Frequency Assignment Problems, *Annals of Operations Research* 153 (1), 79-129, 2007.

[2] Avella P., Sassano A., Vasilev I., Computational Study of large scale p-median problems, *Mathematical Programming* A, 109 (2007) 1, 89-114

[3] Avella P., Mattia S. and Sassano A., Metric Inequalities and the Network Loading Problem, *Discrete Optimization* 4 (2007) 103-114.

[4] Bienstock D. and Mattia S., Using Mixed Integer Programming to Solve Power Grids Blackout Problems, *Discrete Optimization* 4 (2007) 115-141.

[5] Bruni R., Reformulation of the Support Set Selection Problem in the Logical Analysis of Data, Annals of Operations Research Vol. 150(1), 79-92, 2007.

[6] Mannino C., Oriolo G., Ricci F., Chandran S., The stable set problem and the thinness of a graph, *Operations Research Letters*, 35 (1), 1-9, 2007.

Submitted papers, technical reports and others

[7] Bruni R. and Santori A., New Updating Criteria for Conflict-Based Branching Heuristics in DPLL Algorithms for Satisfiability, Discrete Optimization Vol. 5(3), 2008.

[8] Bruni R., Solving Peptide Sequencing as Satisfiability, Computer and Mathematics with Applications Vol. 55(5), 912-923, 2008.

[9] Bruni R., A Combinatorial Optimization Approach for Determining Composition and Sequence of Polymers, Algorithmic Operations Research, in press.

[10] D'Andreagiovanni F., Mannino C., WiMAX Network Planning and Optimization, Tech. Rep. TR02-08 Dipartimento di Informatica e Sistemistica, Università di Roma 1, 2008, submitted to *WiMAX Network Planning and Optimization*, Eds. Yan ZHANG, Auerbach Publications (under major revision).

[11] Mannino C., Mascis A., Real-Time Traffic Control in Metro Stations, to appear in *Operations Research*.

[12] Mannino C., Rossi F., Smriglio S., A Unified View in Planning Broadcasting Networks, Tech. Rep. 08-07, Dipartimento di Informatica e Sistemistica, Università di Roma 1, 2007, submitted to *Networks*.

[13] Mannino C., Marinelli F., Rossi F., Smriglio S., A Tight Reformulation of the Power-and-Frequency Assignment Problem in Wireless Networks, Tech. Rep. TRCS 003/2007, Dip. di Informatica, Università L'Aquila, 2007.

3.3.2 Industrial Economics

This group mainly investigates the theoretical explanations and empirical implications of three interrelated phenomena: (i) technological innovation, (ii) strategic behavior of Multinational Enterprises (MNE) in R&D intensive industries, (iii) national and multilateral policies on foreign direct investment (FDI) and globalization. The main research topics are connected with the analysis of FDI and R&D in oligopolistic industries. Also some topics related with regulation under

asymmetric information are dealt with. We have been collaborating with several European Universities and research institutes, such as SPRU (Sussex University), UK; Universitè Lille 1, France; Norwegian Institute of Foreign Affairs (NUPI), Norway.

Group members

Faculty members Maria Luisa PETIT, Francesca SANNA–RANDACCIO, Roberta SESTINI.

R&D Internationalization The research pursued within this area examines the trade-offs faced by a multinational company when choosing whether to assign a foreign subsidiary an active role in innovation, deciding thus if its R&D should be centralized or, at least partly, decentralized. The model focuses on how the interplay of internal and external knowledge flows interacts with the nature of host market competition to influence the choice of the multinational to effectively disperse internationally its R&D. Our analysis addresses both the case of R&D undertaken abroad in association to production and that of pure research labs abroad [1].

R&D International Production and Asymmetries in Knowledge Trasmission Several topics have been analysed. The first strand of research investigates the interaction between firms' international strategy and innovative performance in an international oligopoly characterized by localized technological spillovers. In particular we have investigated whether the possibility to absorb technological knowledge operating in another country can be an incentive for a firm to invest abroad ("technological sourcing through FDI"). Introducing this "location" element into the analysis, we studied the impact that asymmetries in the degree of transmission of knowledge - due to differences in location- may have on the incentive to innovate and on the mode of foreign expansion [5]. We also dealt with other sources of asymmetry such as unequal know-how management capabilities. We found that a better ability to manage knowledge flows stimulates the firm to invest more in R&D [2].

Cross-border Mergers and Acquisitions and Technology Transfer This line of research has been devoted to identify the optimal FDI mode (greenfield investment or acquisition) in a two country, two firm Cournot model with differing technological levels and country sizes, allowing for asymmetric equilibria. A firm entering the foreign market through greenfield investment has to pay a set up cost, while entry through acquisition involves a bargaining process which determines who will buy whom and at what price. The model explicitly allows for M&A implementation costs. International transfer of technology is also costly, but an acquisition allows the firm to choose the best technological practice in each country. It is found that lower greenfield set up costs (multilateral investment liberalisation) may actually increase the incentives for acquisition. Furthermore, it is shown that a technological leader from a small country needs not only a strong technological lead in order to be the acquirer, but also an efficient know-how management system [3].

Obstacles to Innovation and Multinational Firms in the Italian Regions This research project has analysed how the probability of perceiving as important the obstacles to innovation is affected by different firm-, sector- and region-specific features. Among the firm's characteristics taken into account there are: size; type of ownership, i.e. whether the firm belongs to a foreign-owned group, a nationally-owned group, or is a single domestic firm; firms' innovativeness. The estimated model considers sectoral specificities and includes the macro-area in which the firm is located (North-west; North-east; Centre; South). The empirical analysis is carried out on Italian firm-level data provided by the third Community Innovation Survey (CIS3), with reference to the period 1998-2000. The major finding of this study is that important differences on how obstacles

to innovation are perceived by firms occur both across regions and across types of firms. Overall, as compared to the reference category, which is a non-innovative single domestic firm, located in the South of Italy and operating in the real estate sector, firms located in the North and in the Centre of the country and belonging to either foreign- or Italian-owned groups tend significantly less frequently to perceive obstacles to innovation as relevant [4].

Underprovision of Quality and Regulation Another line of research has aimed at analysing the behaviour of sellers in a market for an experience good, where it is unfeasible to credibly signal quality. We focused on a segmented market where firms, due to a different level of initial investment in human capital, are distinguished into low-type and high-type ones. We found that, with asymmetric information, both low-type and high-type firms choose an optimal quality strictly lower than under full information. Equilibrium profits and consumers' welfare are reduced too. A Self-Regulating Organisation (SRO) is thus introduced: local monopolists can join the association to commit to some minimum quality standard (MQS). It is shown that if all club members are correctly perceived to comply with the MQS, prices and qualities would be set at the same level as with full information. Moreover a SRO represents a self-enforcing credible mechanism if there is an incentive for each member to punish deviant members (for both types). Moreover a SRO is always enforceable for low-type firms, provided there is some consumers' mobility, while it is such for high-type firms only if the population of sellers is not too heterogeneous in terms of skill levels [6].

Journals

[1] Sanna-Randaccio, F. and Veugelers, R. Multinational knowledge spillovers with centralized versus decentralized R&D: a game theoretic approach. *Journal of International Business Studies*, 38 (1), 47–63, 2007.

Conference proceedings

[2] Petit, M.L., Sanna-Randaccio F. and Sestini R. R&D and foreign investment with asymmetries in knowledge transmission. In *Proceedings of the 33rd EIBA 2007 Annual Conference (cd-rom)*.

Submitted papers, technical reports and others

[3] Grunfeld, L. and Sanna-Randaccio, F. Who buys whom in international oligopolies with FDI and technology trasfer? Submitted

[4] Iammarino, S., Sanna-Randaccio, F. and Savona, M. The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. Submitted.

[5] Petit, M.L., Sanna-Randaccio, F. and Sestini, R. Asymmetric knowledge flows and localization with endogenous R&D: a dynamic analysis. Submitted.

[6] Sestini, R. Are You a Doctor or a Quack? Provision of Quality and Self-regulation in a Market for Professional Services. Submitted.

3.3.3 Industrial Organization and Management

Our research field comprises general issues in industrial economics and organization, as well as specific sectors, such as network industries. In particular, we deal with the following topics:

- regulation and competition in the pharmaceutical industry;
- signalling models in international oligopolistic competition;

- regulation and competition in network industries;
- auction-based market mechanisms;
- multicriteria decision making and corporate strategy;
- accounting and finance.

We have worked on a number of applied research projects funded by public institutions and firms. At present we are involved in the following research projects: MIUR (PRIN) "Modelli e metodi per l'analisi degli investimenti e delle scelte tecnologiche nei settori dell'energia elettrica e delle telecomunicazioni", MIUR (FISR) "INTERAGRO metodi e strumenti per la supply chain INTEgRata nell AGRO alimentare". We are also in the scientific committee of the newly established International Center for Competitiveness Studies in the Aviation Industry (ICCSAI).

Group members

Faculty members: Alessandro AVENALI, Domenico LAISE, Claudio LEPORELLI, Giorgio MATTEUCCI, Alberto NASTASI, Pier Luigi PICCARI, Pierfrancesco REVERBERI.
PhD students: Anna D'ANNUNZIO.

Signalling models in international oligopolistic competition We carry out an analysis of the entry strategies in oligopolistic industries in the presence of asymmetric information. In particular we consider a context where a home firm signals her private cost information by expanding in a foreign firm's country. Credible signalling to deter counter-entry may occur through a direct investment (but not through exports), and may even entail entering an unprofitable market. While this produces social benefits, uninformative signalling may be welfare-reducing. Hence, we argue that moderate to high location costs may be socially desirable. We also show that there are not simple monotonic relationships between technology/demand conditions and firms' entry modes. Thus, the signalling interpretation of international expansion makes it possible to explain some controversial empirical findings on a theoretical ground [6].

Regulation and competition in network industries Our research in network industries focuses on both technological choices and regulatory policies in the telecommunication sector. In [9, 12] we define a dynamic model to assess whether and when the ladder of investment regulatory paradigm induces efficient competitive network investment. We find that a multi-period schedule where access charges rise over time can indeed achieve this goal. Then, we show that the principles underlying this schedule can also be effective when entrants strategies differ over geographical areas, rather than over time. In [10] we assess if vertical separation of the telecommunications incumbent may be an effective and proportionate remedy when the access network is an enduring economic bottleneck. We show that, despite efficiency losses of vertical disintegration, mandatory separation improves quality investment and welfare provided that the demand-side investment spillover, or the rival firms (perceived) service quality is sufficiently high. Finally, in view of the prospective deployment of next generation access networks, we discuss the potential conflict between promoting competition, and ensuring the incumbents investment [5].

Auction-based market mechanisms We study how scarce resources can be traded via auction mechanisms. In particular, we focus on combinatorial auctions, which enhance the efficiency of market exchanges in environments characterized by complementarity or substitutability relations between the goods at sale [1]. However, this type of auction requires dealing with hard optimization problems, that require specific solution techniques [2].

Multicriteria managerial decision making Our research illustrates the advantages of the multicriteria methodology, founded on the notion of outranking methods, applied to managerial

decision making problems. Outranking paradigms are satisfying - heuristic and not optimizing algorithms, able to make effective and formally robust multicriteria choice without the aggregation of the set of conflicting criteria into a single objective function. [3, 4, 7, 8].

In [11] we study the role of the exchange of structured data across information systems within inter-organization business processes. We assume that data are exchanged under given condition of quality and prices. We describe a brokering algorithm for obtaining data from peers, by minimizing the overall cost under quality requirements constraints.

Journals

[1] Avenali A. and Bassanini A. Simulating combinatorial auctions through automated rational agents. *Decision Support Systems*, 43, pp. 211-228, 2007.

[2] Avenali A. Resolution Branch and Bound and an Application: the Maximum Weighted Stable Set Problem. *Operations Research*, 55/5, pp. 932-948, 2007.

[3] Biggiero L. and Laise D. On Choosing Governance Structures: Theoretical and methodological issues. *Human Systems Management*, 26, pp. 69-84, 2007.

[4] Laise D. Strumenti per analizzare, valutare e migliorare la qualità del servizio scolastico. *De Qualitate*, pp. 10-22, Febbraio 2007.

[5] Leporelli C. Le reti di banda larga di nuova generazione: quali effetti sugli utenti e sulla concorrenza, *Consumatori, diritti e mercato*, 3, 2007.

[6] Nastasi A. and Reverberi P. Foreign market entry strategies under asymmetric information, *Review of international economics*, 15, pp. 758-781, 2007.

Book

[7] Laise D. *Economia delle organizzazioni: principi e metodi di progettazione*, Mc Graw - Hill, Milano, 2007.

Articles in books

[8] Iazzolino G. and Laise D. On Shareholder Value Analysis: Maximizing and Satisfacing Paradigms. In Linda M. Cornwall editor, *Banking and Finance Issues and Developments*, Nova Science Publishers, N.Y. , pp. 179-200.

Conference proceedings

[9] Avenali A., Matteucci G. and Reverberi P. Dynamic access pricing and incentives to invest in alternative infrastructures. *European Association for Research in Industrial Economics EARIE Conference 2007*, Valencia, Spain, September 2007.

[10] Avenali A., Matteucci G. and Reverberi P. Separazione verticale e investimenti nelle reti di telecomunicazioni. Atti della XVIII Riunione Scientifica Annuale dell'Associazione Italiana di Ingegneria Gestionale AiIG, Milano, Italy, October 2007.

Submitted papers, technical reports and others

[11] Avenali A., Bertolazzi P., Batini C., Missier P.. Brokering infrastructure for minimum cost data procurement based on quality - quantity models. *Decision Support Systems*, Accepted for publication, 2007.

[12] Avenali A., Matteucci G. and Reverberi P.. Dynamic access pricing and incentives to invest in alternative infrastructures. submitted, 2007.

3.3.4 Modelling, Data Analysis and Optimization

The research takes advantage of methodologies coming from diverse disciplines such as large scale dynamical modelling, simulation and optimization. Reference applications are in the broad field of complex system management science with the aim of developing models and testing efficient algorithms for processing large amount of real world data coming from industrial and biosystems engineering by means of an integrated approach.

Current main research areas are: Embedded and Reactive Real-Time Systems in Automotive Management, Computational Optimization in Systems Biology, Image Processing and Computer Vision, Complex Algorithms and Data Mining.

Ongoing projects:

- Advanced research on architectures and design of electronic systems
- Experimental analysis, modelling and simulation of the DNA damage response in *E. coli*
- Computational methods for the analysis of genome wide expression data
- Topological features and criticalities in metabolic networks
- Robust and efficient procedures for images and videosequences segmentation
- Analysis and characterization of the microstructure of materials from light optical microscope images
- Design of Human Computer Interfaces for disabled people based on videosequences analysis
- Analysis of Human Behavior for surveillance and monitoring in computer vision

International and national collaborations:

Istituto di Biologia e Patologia Molecolari (CNR), Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione (INRAN), Istituto Superiore di Sanità, Department of Biomedical Engineering (Boston University), IASI (CNR), PARADES, Dept. of Materiali, Strutture, Ambiente e Territorio (Università di Cassino), Dept. of Ingegneria Chimica, dei Materiali delle Materie Prime e Metallurgia (Università Sapienza di Roma), SELEX-Sistemi Integrati S.p.A.

Group members

Faculty members Luca BENVENUTI, Alberto DE SANTIS and Lorenzo FARINA.

Embedded and Reactive Real-Time Systems in Management Embedded systems are electronic components integrated onto a physical plant. Automotive electronic design is certainly one of the most attractive and promising application domains for embedded systems. In fact, in today cars, the electronic control system is a networked system with an embedded controller dedicated to each subsystem, e.g. engine control unit,gear-box controller, anti-lock braking system (ABS), dashboard controller, and vehicle dynamic control (VDC). The embedded controllers interact by communicating over a network and system integration has become a nightmare in the automotive industry. On one hand, this is due to the lack of an overall understanding of the interplay of sub-systems and of the difficulties encountered in integrating very complex parts. On the other hand the complexity of the embedded controllers is necessary in order to comply with ever increasing demands on functionality and time-to-market pressure.

Computational Optimization in Systems Biology Computational optimization in systems biology is a research program that links biologists and engineers in a multi-disciplinary approach to the systemic analysis of large scale and complex dynamical biological phenomena. The main interest is on theoretical aspects of modelling and on applicative topics in systems biology. Main results in the area of systems biology are presented in reference [4] where a dynamical model taking into account the effect of specific mRNA degradation on the shape of gene expression time series is developed, and the concept of "dynamically co-regulated" genes is accordingly introduced as the goodness of fit to such a model (called dynamic R2). An entirely new set of gene pairs can be selected as putative transcriptionally co-regulated by the presence of a high dynamic R2. In [2] is shown that cell cultures display a sort of "ecology-in-a-plate" giving rise to a rich dynamics of gene expression that are independent from reproductive cycles, hence contradicting simple ergodic assumptions. The topological bases of essentiality in the yeast metabolic network from the perspective of double mutations are the subject of the study presented in [3].
The publications relevant to this area are: [4], [5], [6], [14].

Signal Processing and Computer Vision Digital signal processing is concerned with the theoretical and practical aspects of representing and extracting information from real data; it has a significant impact in most of the scientific and technical areas of management sciences. Current applications of interest in the research group are within the areas of industrial engineering , man-machine interaction and medical technology, science of materials and mechanical structures fault diagnosis [4], [6], [10], [11]. Advanced applications include the real-time analysis of video-sequences in the framework of Human Computer Interface for disabled people [14], and in the development and design of surveillance systems for active monitoring of public areas. Our study lies within the framework of the variational approach to the image segmentation, formulated as a global optimization problem. The main results are in [5] where a new discrete level set approach is developed, that retains the accuracy of the continuum models based on nonlinear partial differential equations, but it is more robust and numerically efficient. This makes real time applications really feasible.

The publications relevant to this area are: [1, 2, 3, 7, 8, 9, 10, 11, 12, 13].

Journals

[1] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Optimal Binarization of Images by Neural Networks, *Pattern Analysis and Applications*, 10:2, 125-133, 2007.

[2] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Procedure alternative per l'analisi quantitativa di immagini applicate alle ghise sferoidali, *La Metallurgia Italiana*, 6, 15-23, 2007.

[3] De Santis A., Iacoviello D., Discrete level set approach to image segmentation, *Signal, Image and Video Processing*, 1:4, 303-320,2007.

[4] Farina L., De Santis A., Morelli G. and Ruberti I., Dynamic measure of genes co-regulation, *IET System Biology*, 1, 10-17, 2007.

[5] Giuliani A., Tsuchiya M., Zhen Y., Colosimo A., Palumbo M.C., Farina L., Crescenzi M., Mazzola A., Negri R., Bianchi M., Gene expression waves: cell cycle independent collective dynamics in cultured cells, *FEBS Journal*, 274, 2878-2886, 2007.

[6] Palumbo M.C., Colosimo A., Giuliani A. and Farina L., Essentiality is an emergent property of metabolic network wiring, *FEBS Letters*, 581, 2485-2489, 2007.

Conference proceedings

[7] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Meccanismi di danneggiamento nelle ghise sferoidali ferrito-perlitiche, Atti del Congresso IGF 19, Milano, Luglio 2007.

[8] De Santis A., Iacoviello D., Video sequences analysis for eye tracking, International VIP-Image, ECCOMAS Thematic Conference on Computational Vision and Medical Image Processing, Porto, October 2007.

Submitted papers, technical reports and others

[9] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Quantitative shape evaluation of graphite elements in ductile iron, *Journal of Material Processing and Technology*, to appear.

[10] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Discrete image model and segmentation for microstructure features identification in ductile irons, *International Journal for Computational Vision and Biomechanics*, to appear.

[11] De Santis A., Iacoviello D., Optimal Piecewise-Constant segmentation of Images by Neural Networks, *IEE Proc. Visual Image and Signal Processing*, to appear.

[12] De Santis A., Iacoviello D., A robust eye tracking procedure for medical and industrial applications, *Computational Methods in Applied Sciences (Eccomas Volumes) – Advances in computational vision and medical images processing: methods and application*, submitted.

[13] De Santis A., Iacoviello D., Robust real time eye tracking for computer interface for disabled people, *Image and Vision Computing*, submitted.

[14] Palumbo M.C., Farina L., De Santis A., Giuliani A., Colosimo A., Morelli G. and Ruberti I., Collective Behaviour in Gene Regulation: Post-transcriptional Regulation and the Temporal Compartmentalization of Cellular cycles, *FEBS Journal*, to appear.

3.3.5 Nonlinear Optimization

The research of the Nonlinear Optimization group is devoted to the theoretical analysis, the development and the computational experimentation of methods for solving Nonlinear Optimization problems. Problems arising from real world applications are also an important part of the research activity.
The Nonlinear Optimization group is currently cooperating with: Istituto di Analisi dei Sistemi ed Informatica IASI–CNR; Dipartimento di Ingegneria Elettrica, Università di L'Aquila; Dipartimento di Sistemi ed Informatica, Università di Firenze; Istituto Nazionale per Studi ed Esperienze di Architettura Navale INSEAN; Institut für Statistik ISDS, Universität Wien; Department of Computer Science and Information Engineering, National Taiwan University; Institute of Mathematics, University of Würzburg; Department of Mathematical Sciences, Rensselaer Polytechnic Institute.
During 2007, the Nonlinear Optimization group has been mainly involved in the MIUR–FIRB National Research Program "Large Scale Nonlinear Optimization" and in the MIUR–PRIN National Research Program "Problemi, metodi e algoritmi innovativi nell'Ottimizzazione Nonlineare".

Faculty members Gianni DI PILLO, Francisco FACCHINEI, Luigi GRIPPO, Stefano LUCIDI, Laura PALAGI, Massimo ROMA.
Post-docs Veronica PICCIALLI.
PhD students Francesco RINALDI, Arnaldo RISI .
Visitors Giovanni FASANO, Giampaolo LIUZZI, Marco SCIANDRONE.

Unconstrained Optimization The research activity in unconstrained optimization focused on the definition of new methods for solving large scale problems which enjoy both good theoretical properties and computational efficiency. In particular, Newton–Krylov methods have been considered, dealing with two fundamental aspects: the need of efficiently tackling nonconvex problems and the possibility of defining an effective preconditioning strategy. In this framework, in [3], new Conjugate Gradient–type schemes have been introduced to efficiently tackle indefinite problems in the large scale setting. New preconditioning strategies have been introduced in [11] and in [12]. In particular, in [11] in the context of truncated Newton methods, a diagonal preconditioning has been studied based on a scaling on the Hessian matrix without the explicit knowledge of its elements. Moreover a preconditioning strategy based on the iterative approximate computation of the inverse of the Hessian matrix has been considered [12]. Moreover, nonmonotone schemes have been further developed for defining derivative–free iterative algorithms for the solution of large systems of nonlinear equations [4]. Finally, a derivative–free algorithms for the solution of nonlinear systems of inequalities has been proposed in [16].

Constrained Optimization Problems with general constraints and problems with constraints of a particular structure have been addressed. In particular, inequality constrained problems have been considered and a truncated primal–dual algorithm converging to a KKT point for the solution of large scale problems has been defined [9]. Moreover a derivative–free algorithm for inequality constrained problems has been introduced in [17]. The approach is based on the use of a nondifferentiable exact penalty function. Another research topic of interest concerns the so called *Support Vector Machines* (SVM). It considers convex quadratic problems with one linear equality constraint and simple bounds on the variables, where the dimension is usually so large that standard methods are not reliable. The activity focused on the definition of decomposition algorithms with theoretical convergence properties and showing good behaviour in terms of computational time and accuracy of the solution [15, 5]. Moreover, nonlinear programming problems arising as formulations of low rank Semidefinite Programming (SDP) problems have been considered [13]. They are important formulations of the max cut problem on a graph. A globally convergent algorithm has been defined and tested on max cut problems available in literature.

Equilibrium problems Another topic of interest was the study of Generalized Nash Equilibrium Problems (GNEP). GNEPs are a variant of the usual Nash Equilibirum Problem wherein the feasible sets of the players depend on the other players' strategies. The survey paper [1] deals with their main properties and describes the solution algorithms. Moreover, Newton type methods have been proposed for these problems [10] and the reduction of a GNEP to a variational inequality was considered [2]. Finally, a novel GNEP model for the power allocation with rate constraints in telecommunications has been proposed in [18]. For this model, existence and uniqueness of the solution is analyzed and decomposition algorithms are developed. It should be noted that this is probably the only case in literature for which decomposition algorithms are shown to be convergent for a non trivial GNEP.

Global Optimization Globally convergent modifications of the algorithm Particle Swarm Optimization (PSO) for the solution of global optimization problems have been developed. In particular, new theoretical properties have been proved and the reformulation of PSO algorithm in terms of dynamic system has been preformed [7, 6].

Applications An important aspect of the research concerned the definition of optimization algorithms for solving problems arising from real world applications. In particular, [14] deals with an model used in epidemiology and [8] a problem arising from electrical power distribution.

Journals

[1] Facchinei F. and Kanzow C. Generalized Nash equilibrium problems. *4OR*, 5:173–210, 2007.

[2] Facchinei F., Fischer A. and Piccialli V. On generalized Nash games and variational inequalities. *Operations Research Letters*, 35:159–164, 2007.

[3] Fasano G. and Roma M. Iterative computation of negative curvature directions in large scale unconstrained optimization. *Computational Optimization and Applications*, 38:81–104, 2007.

[4] Grippo L. and Sciandrone M. Nonmonotone derivative-free methods for nonlinear equations. *Computational Optimization and Applications*, 37:297–328, 2007.

[5] Lucidi S., Palagi L., Risi A. and Sciandrone M. A convergent decomposition algorithm for support vector machines. *Computational Optimization and Applications*, 38:217–234, 2007.

Submitted papers, technical reports and others

[6] Campana E.F., Fasano G., Peri D. and Pinto A. Dynamic system analysis for the selection of parameters and initial population, in particle swarm optimization. Submitted to *Journal of Global Optimization*.

[7] Campana E.F., Fasano G., Peri D. and Pinto A. Globally convergent modifications of particle swarm optimization for unconstrained optimization. Submitted to *Journal of Global Optimization*.

[8] Casolino G.M., Liuzzi G. and Losi A. Unit commitment by nonlinear mixed variable programming. Submitted to *Optimization and Engineering*.

[9] Di Pillo G., Liuzzi G., Lucidi S. and Palagi L. A truncated Newton method in an augmented lagrangian framework for nonlinear programming. Technical Report 09–2007, Dipartimento di Informatica e Sistemistica "A. Ruberti", Università di Roma "La Sapienza", 2007. Submitted to *Computational Optimization and Applications*.

[10] Facchinei F., Fischer A. and Piccialli V. Generalized Nash equilibrium problems and Newton methods. To appear in *Mathematical Programming*.

[11] Fasano G. and Roma M. On the iterative computation of ℓ_2-norm scaling based preconditioner. Technical Report 2007–002, INSEAN, Roma, 2007.

[12] Fasano G. and Roma M. Preconditioning Newton-Krylov methods in non convex large scale optimization. Technical Report 01–2007, Dipartimento di Informatica e Sistemistica "A. Ruberti", Università di Roma "La Sapienza", 2007.

[13] Grippo L., Palagi L. and Piccialli V. An unconstrained minimization method for solving low rank SDP relaxations of the max cut problem. Technical Report 07–2007, Dipartimento di Informatica e Sistemistica "A. Ruberti", Università di Roma "La Sapienza", 2007. Submitted to *Mathematical Programming*.

[14] Iacoviello D. and Liuzzi G. Fixed/free final time SIR epidemic models with multiple controls. To appear in *International Journal of Simulation Modelling*.

[15] Lin C.-J., Lucidi S., Palagi L., Risi A. and Sciandrone M. A decomposition algorithm model for singly linearly constrained problems subject to lower and upper bounds. Technical Report 02–2007, Dipartimento di Informatica e Sistemistica "A. Ruberti", Università di Roma "La Sapienza", 2007. To appear in *Journal of Optimization Theory and Applications*.

[16] Liuzzi G. and Lucidi S. A derivative–free algorithm for systems of nonlinear inequalities. To appear in *Optimization Letters*.

[17] Liuzzi G. and Lucidi S. A derivative-free algorithm for inequality constrained nonlinear programming. Technical Report 659, IASI-CNR, 2007. Submitted to *SIAM Journal on Optimization*.

[18] Pang J.-S., Scutari G., Facchinei F. and Wang C. Distributed power allocation with rate constraints in Gaussian parallel interference channels. Technical Report 05–2007, Dipartimento di Informatica e Sistemistica A. Ruberti, Sapienza Università di Roma, 2007. To appear in *IEEE Transaction on Information Theory*.