



DIPARTIMENTO DI INFORMATICA  
E SISTEMISTICA ANTONIO RUBERTI



SAPIENZA  
UNIVERSITÀ DI ROMA

Research report 2008

**Dipartimento di Informatica e Sistemistica Antonio Ruberti  
Sapienza Università di Roma**

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# 1 Introduction

The present report provides an overview of the research carried out at the Department of Computer and System Sciences Antonio Ruberti (DIS) of the Sapienza University of Rome, during the year 2008.

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 in computer, system, 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 2008 consists of 30 full professors, 19 associate professors, and 16 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, and management. The teaching activity is not illustrated in this report; a description may be found at [http://www.dis.uniroma1.it/index.php?option=com\\_content&task=view&id=15&Itemid=29](http://www.dis.uniroma1.it/index.php?option=com_content&task=view&id=15&Itemid=29)

Furthermore, DIS offers two Ph.D. programs, and cooperates with three Ph.D. programs offered by other departments. They are briefly described in Section 2 of this report.

The main research areas of DIS are:

- Computer science
- System 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 that appeared in 2008.



## 2 General Information

### 2.1 Location

The location of DIS is the building known as Silvio Pellico, in 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 building in 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.

During the year 2008, 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 2008 were:

Nicola CACACE	L'informatico e la badante	Jan. 7, 2008
Alessandro TREVES	Come funziona la memoria	Mar. 13, 2008
Ada GENTILE	Dall'opera alla musica da film Goffredo Petrassi: un artista multiforme	Mar. 31, 2008
Enrico ALLEVA (with Paolo MAURI, Elisabetta VISALBERGHI, Andrea CAMILLERI)	La mente animale	May 6, 2008

#### 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 Camil DEMETRESCU

*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 new 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

*ROCOCO - RObot COgnitivi COoperanti*

Via Ariosto 25 - - basement

The laboratory of SPQR (Soccer Player Quadruped Robots) teams participating in RoboCup, AIBO, NAO and Rescue Robots.

Web: <http://labrococo.dis.uniroma1.it/>

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 MECCELLA

*Systems and Control Laboratory*

Via Ariosto 25 - basement

The laboratory is devoted to the development and experimental verification of new control strategies.

Web: [http://labsis.dis.uniroma1.it/LSW\\_R2/index.html](http://labsis.dis.uniroma1.it/LSW_R2/index.html)

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://wiserver.dis.uniroma1.it/cms/>

Head Andrea VITALETTI

In addition, DIS run - until September 2008 - 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  
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  
Leonardo QUERZONI (starting November 2008)  
Roberta SESTINI  
Marilena VENDITTELLI  
Andrea VITALETTI

*Contract professors*

Fabio CELANI

**Staff***Research associates and post docs*

Carola AIELLO  
Enrico BERTINI  
Vincenzo BONIFACI  
Yann BUSNEL  
Silvia CANALE  
Luigi FREDA  
Giorgio KOCH  
Luigi LAURA  
Eleonora MAMBRINI  
Toni MANCINI  
Sara MATTIA  
Veronica PICCIALLI  
Antonio PIETRABISSA  
Antonella POGGI  
Leonardo QUERZONI  
Marco RUZZI  
Elena SACCHETTINO  
Piotr SANKOWSKY  
Fabiano SARRACCO  
Vincenzo SURACI  
Sara TUCCI PIERGIOVANNI

*Administration staff*

Amelia ARRICALE  
Flavia CAGNIZI (starting June 2008)  
Antonietta CANGELLI  
Beatrice DE CARLO  
Tiziana VALENTINI  
Maria Pia VANDILLI

*Technical staff*

Anna Paola DI RISIO (on leave)  
Giuseppe FILACI  
Tiziana TONI

*Auxiliary services*

Pia BONANNI  
Antonio SIMEONI

*Librarian*

Laura ARMIERO

**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 Electric, Computer and System Sciences) of the University of Bologna, in Operations Research, hosted by the Department of Probability and Statistics of the Sapienza University of Rome, and in Economics and Management of Technology hosted by the Department of Management Engineering of the University of Bergamo.

### 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

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Eugenio MATTEI

### Computer Engineering

The council of professors of the Ph.D. program in Computer Engineering is coordinated by Maurizio LENZERINI until October 31, then by Roberto BALDONI.

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

New admissions for the XXIV course are:

Lorenzo BERGAMINI  
 Claudio CORONA  
 Pierangelo DI SANZO  
 Luca FILIPPONI  
 Letizia MARCHEGIANI  
 Roberto PALMIERI  
 Marco PLATANIA  
 Domenico Fabio SAVO

### **Economics and Management of Technology**

DIS participates in the Ph.D. program in Economics and Management of Technology coordinated by the Department of Management Engineering of the University of Bergamo. The research topics are: Industrial Organization, Economics of Innovation, Management and Finance.

*Ph.D. students (working at DIS)*

XXII course

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Anna D'ANNUNZIO

### **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

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Arnaldo RISI      Francesco RINALDI      Fabio D'ANDREAGIOVANNI

New admissions for the XXIV course are:

Marianna DE SANTIS  
 Andrea IANNI  
 Carla MICHINI  
 Gianluca MORELLI  
 Mauro PIACENTINI  
 Claudia SNELS

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

New admissions for the XXIV course are:

Laura FOGLIATI  
 Fabrizio FLACCO  
 Lorenzo LAMPARIELLO  
 Federico PAPA  
 Mattia PETRUCCIANI  
 Simone SAGRATELLA  
 Paolo STEGNANO

## Ph.D. theses completed in 2008

### Computer Engineering

Luca ALLULLI

*Cache Oblivious Computation of Shortest Paths: Theoretical and Practical Issues*

Advisor: Fabrizio D'AMORE

February 2008

Luigi DRAGONE

*Modeling and Reasoning about e-services in Cooperative Information Systems*

Advisor: Riccardo ROSATI

February 2008

Andrea RIBICHINI

*Streaming Algorithms for Graph Problems*

Advisor: Camil DEMETRESCU

February 2008

Vittorio Amos ZIPARO  
*Multi-Robot Teams for Multi-Objective Tasks*  
Advisor: Daniele NARDI  
February 2008

*Operations research*

Arnaldo RISI  
*Convergent Decomposition Methods for Support Vector Machines*  
Advisor: Marco SCIANDRONE  
February 2008

*Systems Engineering*

Gianluca BALDESI  
*Modeling, Simulation and Validation of Control Strategies for Space Launcher (in Italian)*  
Advisor: Salvatore MONACO  
February 2008

Leonardo CAVARISCHIA  
*Hierarchical Process Control: a Geometric Approach*  
Advisor: Leonardo LANARI  
February 2008

Andrea CHERUBINI  
*Vision-based Techniques for Following Paths with Mobile Robots*  
Advisor: Giuseppe ORIOLO  
February 2008

Paolo ROBUFFO GIORDANO  
*Visual Estimation and Control for Robot Manipulation Systems*  
Advisor: Alessandro DE LUCA  
February 2008

Vincenzo SURACI  
*Technology Independent Resource Management in Next Generation Networks: Routing and Connection Admission Control Procedures*  
Advisor: Francesco DELLI PRISCOLI  
February 2008

### Visiting scientists

DIS hosts visiting scientists and scholars from all over the world. Here we list the visitors that spent at least a month at DIS, during 2008.

Gabriele ABERMANN, Salzburg University of Applied Sciences, Austria (January)  
 Immanuel BOMZE, University of Wien, Austria (February)  
 Carsten Skovmose KALLESØE, Grundfos Management A/S, Denmark (March - May)  
 Phokion KOLAITIS, IBM Almaden research Center, CA, USA ( May)  
 Yves LESPERANCE, York University, Toronto, Canada (June - July)  
 Adrian S. LEWIS, Cornell University, USA (January - May)  
 Leonid LIBKIN, University of Edinburgh, UK (June - July)  
 Ravi PRAKASH, University of Texas at Dallas, USA (September)  
 Idith KEIDAR, Technion, Israel (October)  
 Pauli MIETTINEN, Helsinki University of Technology, Finland (December 2007- March 2008)  
 Michael L. OVERTON, New York University, USA (February - April)  
 Mohit SINGH, Carnegie Mellon University, USA (December 2007- January 2008)

## 2.5 Contracts

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

### Contracts with the European Union (E.U.)

- E.U., 205.500, TONES, Thinking Ontologies, G. De Giacomo (up to 31/12/08)
- E.U., 236.500, SATSIX, Satellite-based communications system within IPv6 networks, F. Delli Priscoli (up to 31/05/08)
- E.U., 193.520, AEOLUS, Algorithmic principles for building efficient overlay computers, A. Marchetti Spaccamela (up to 31/08/08)
- E.U., 121.365, CYBERWALK, The CyberCarpet: Enabling Omni-directional Walking in Virtual Worlds, A. De Luca (up to 31/03/08)
- E.U., 540.000, DELIS, Dynamically Evolving Large Scale Information Systems, S. Leonardi (up to 31/03/2008)
- E.U., 100.237, VIEW-FINDER, Vision and Chemiresistor Equipped Web-connected Finding Robots, F. Pirri (up to 30/11/09)
- 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 30/03/09)

- E.U., 195.489, PHRIENDS, Physical Human-Robot Interaction: depENDability and Safety, A. De Luca (up to 30/09/09)
- E.U., 160.335, RESIST, Resilience for Survivability in IST, R. Baldoni (up to 30/03/09)
- 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 31/08/09)
- E.U., 54.420, PANORAMA, Pervasive Adaptation Network for the Organisation of the Research Agenda and The Management of Activities, A. Marchetti Spaccamela (up to 31/12/2010)
- E.U., 200.000, FRONTS, Foundations of Adaptive Networked Societies of Tiny Artefacts, A. Marchetti Spaccamela. (up to 31/12/2010)
- E.U., 256.500, P2P-NEXT, Next Generation Peer-to-Peer Content Delivery Platform, F. Delli Priscoli (up to 31/12/2011)
- E.U., 20.491, VisMaster CA, Visual Analytics Mastering the Information Age, Grant Agreement Number 225924, G. Santucci (up to 31/07/2010)
- E.U., 570.000, SM4All, Smart homes for all: An embedded middleware platform for pervasive and immersive environments for all, R. Baldoni (up to 31/07/2011)

### Contracts with Italian Institutions

- RCOST-UNISANNIO, 207.900, FISR Progetto INTERAGRO, Metodi e Strumenti per la supply chain INTEgRata nell'AGRO alimentare, A. Sassano (up to 05/12/09)
- MIUR, 380.800, APICE - Algoritmi per la Pianificazione Integrata e Controllo di reti wireless Eterogenee, F. Delli Priscoli (up to 30/06/09)
- MIUR, 36.500, MAINSTREAM - Algoritmi per strutture informative di grandi dimensioni e "data streams," G. Ausiello (up to 31/01/09)
- MIUR, 39.800, PRIN: Problemi e Metodi Innovativi nell'Ottimizzazione Nonlineare, G. Di Pillo (up to 30/01/2008)
- MIUR, 33.585, SICURA - Sicurezza per l'Interazione del Contatto tra Umani, Robot e Ambiente, A. De Luca (up to 21/09/10)
- MIUR, FIRB 2003, 206.186+140.000, eG4M - eGovernment for Mediterranean Countries, T. Catarci and R. Baldoni (up to 30/04/09)
- MIUR, FIRB RBIN047MH9, 225.000, International Italian-Israelian cooperation, A. Marchetti Spaccamela (up to 31/07/09)
- MINISTERO DELLA GIUSTIZIA, 113.034, Supporto scientifico e supervisione per la revisione e la realizzazione dei sistemi di infrastruttura per il processo telematico del Ministero della Giustizia, R. Baldoni (up to 18/10/09)
- DIP. DI INGEGNERIA-Università degli Studi del Sannio, 80.000, Studio e sviluppo di data mining per problemi di gestione e controllo di reti di telecomunicazioni, A. Sassano (up to 31/02/09)
- MIUR, 28.000, PRIN: Ottimizzazione Nonlineare, Disequazioni Variazionali e Problemi di Equilibrio, G. Di Pillo (up to 21/09/2010).

### 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 (up to 09/03/08)
- C.M. SISTEMI, 50.000, Studio di metodi e linguaggi per la rappresentazione e descrizione di ontologie, M. Lenzerini (up to 10/03/08)
- IBM ITALIA, 30.000, Accordo T.S.A., M. Lenzerini (up to 31/12/2008)
- IBM Research USA 7.000 USD, Donation for the study of artifact-centric workflow, G. De Giacomo (2008)
- ELSAG DATAMAT, 375.000, Studio/Ricerca per il progetto "M3-CAST" Servizi mobili multimediali in Multicast su reti DVB-T e UMTS, F. Delli Priscoli, (up to 23/02/09)
- TELECOM ITALIA, 40.000, Servizio sperimentale enterprise 2.0, S. Leonardi, (up to 28/09/08)
- THALES ALENIA SPACE ITALIA, 87.000, GAPACOM, Attività di ricerca e formazione, D. Nardi (up to 31/12/2008)
- TELECOM ITALIA Laboratories, 35.000, Quality of Service in phone conversations based on peer-to-peer systems, R. Baldoni, (up to 01/06/2008)
- TERNA S.p.A, 50.000, Monitoraggio di parametri critici nel controllo primario in frequenza nella rete elettrica nazionale, S. Monaco

### Research Agreements (Convenzioni)

- Consorzio Interuniversitario Nazionale per l'Informatica (CINI) (up to 24/04/2011)
- Fondazione Ugo Bordoni (FUB) (up to 07/03/2011)
- Nous Informatica srl (up to 10/07/2011)

## 2.6 Seminars and Workshops

Many scientists are invited to deliver seminars at DIS each year. Below is a list of seminars for the year 2008, in chronological order. Also the Workshops organized at DIS are reported, with the exception of the project meetings.

- January 23 - 25, Gabriele Abermann, University of Salzburg, *Presentation techniques for engineers and technical English.*
- January 31, Adrian Lewis, Cornell University, *Nonsmoothness and optimization.*
- February 1, Dennis Lucarelli, Johns Hopkins University, *Distributed probabilistic inference for network localization using radio interferometric ranging.*
- February 5, Ismael Regis de Farias, University at Buffalo, *Cardinality constrained optimization.*
- February 7, Ismael Regis de Farias, University at Buffalo, *Valid inequalities for cardinality constrained optimization sets.*
- February 8, Paolo Giorgini, University of Trento *Agent-Oriented analysis and design: The Tropos approach.*

- February 13, Immanuel Bomze, University of Wien  
*Thrill and challenge of imperfection - combinatorial optimization contacts and test instances for copositive programming.*
- February 20, Paul Wollan, University of Hamburg, *Complete minors in huge graphs.*
- February 21, Yoshihiko Nakamura, University of Tokyo, *Statistical methods for whole body communication of humanoid robot and human.*
- February 29, Gian Diego Tipaldi, DIS, Sapienza University of Rome, *Automated synthesis of robot behaviors.*
- March 4, Michael Overton, Courant Institute of Mathematical Sciences, *Nonsmooth, nonconvex optimization.*
- March 6, Francesca Cirulli and Enrico Alleva, Istituto Superiore di Sanità, *Emozioni robotiche.*
- March 6, Ali Jadbabie, University of Pennsylvania, *From distributed motion coordination in multi-vehicle systems to coverage in sensor networks: interplay of graph theory and algebraic topology with control and dynamical systems.*
- March 13, Fabio Schoen, University of Firenze, *Applicazioni dell'ottimizzazione globale: dalla "Circle Packing Contest" ai cluster bi-atomici ed oltre.*
- March 27, Andrea Vitaletti, DIS, Sapienza University of Rome, *The kaleidoscopic world of wireless sensor networks.*
- March 28, Giuseppe Nicosia, University of Catania, *Population-based optimization algorithms for robust circuit design and bioinformatics problems.*
- April 3, Nahum Gershon, The MITRE Corporation, *Exploring social media.*
- April 7, Imre Leader, Trinity College, Cambridge, *Infinite games.*
- April 10, Fiora Pirri, DIS, Sapienza University of Rome, *Vision systems.*
- May 2, Bezalel Gavish, Southern Methodist University, *Tree based combinatorial optimization problems in telecommunication networks.*
- May 5, Christian Micheloni, University of Udine, *Real time image processing for active monitoring of wide areas.*
- May 15, Riccardo Rosati, DIS, Sapienza University of Rome, *Ontologies, description logics, and DL-Lite.*
- May 21 -29, Debora Donato and Ravi Kumar, Yahoo! Research, *Social networking: models and applications.*
- May 22, Phokion Kolaitis, IBM Almaden Research Center, *Composing and inverting schema mappings.*
- May 23, Nikhil Devanur, Georgia Institute of Technology, *New geometric relaxations for the steiner tree problem and their algorithmic consequences.*
- May 29, Martin Charles Golumbic, University of Haifa, *Algorithmic graph theory and its applications.*
- June 5, Stefano Leonardi, DIS, Sapienza University of Rome, *Graph mining and its applications to reputation management in networks.*

- June 13, Giuseppe Boccignone, DIIIIE - University of Salerno, *Vision between action and perception*.
- June 13, Gianpaolo Oriolo, University of Rome Tor Vergata, *The stable set problem on claw-free graphs*.
- June 16, Kathrin Hoffmann, Technical University Berlin, *Independence of Net Transformation and Token Firing in Reconfigurable P/T-Systems*.
- June 23 – 25, Massimo Mecella, DIS, Sapienza University of Rome, *IEEE WETICE 2008*.
- June 26, Leonid Libkin, University of Edinburgh *Logics for Unranked Trees: An Overview*.
- June 27, Daniel Bienstock, Columbia University *New results on knapsack reformulation*.
- June 30, Ashwin Ram, College of Computing, Georgia Tech *CBR for Game AI*.
- July 10, Silvio Salza, DIS, Sapienza University of Rome *Moving from paper to digital documents, the new challenge for the Italian Public Administration*.
- September 17, Kurt Konolige, Willow Garage *An Introduction to Willow Garage– Personal Robot 2, and some stereo VSLAM research*.
- September 19, A. Fazel Famili, National Research Council Canada *Knowledge Discovery in Data Rich Environments: Case Studies, Complexities, and Challenges*.
- September 25, Beniamino Accattoli, DIS, Sapienza University of Rome *Introduction to linear logic and to linear logic programming*.
- September 26, Beniamino Accattoli, DIS, Sapienza University of Rome *Deductive planning and other specifications in linear logic*.
- September 30, Luigia Carlucci Aiello, DIS, Sapienza University of Rome *Workshop on Educational Robotics*.
- October 9, Ravi Prakash, University of Texas, *RF in the Jungle: Effect of Environment Assumptions on Wireless Experiment Repeatability*.
- October 16, Idit Keidar, Technion - Israel Institute of Technology, *Brahms: Byzantine Resilient Random Membership Sampling*.
- October 23, Luca Becchetti, DIS, Sapienza University of Rome, *Efficient mining of complex networks*.
- November 3, Federico Thomas, IRI Technical University of Catalonia, *Nonholonomic Parallel Robots*.
- November 11, Raffaele Giancarlo, University of Palermo, *Alignment-free Classification and Comparison of Biological Sequences and Structures*.
- November 20, Domenico Daniele Bloisi, DIS, Sapienza University of Rome, *An introduction to Alternating-time Temporal Logic*.
- November 28, Balder ten Cate, ILPS - University of Amsterdam, *Structural Characterizations of Schema-Mapping Languages*.
- December 4, Yann Busnel, DIS, Sapienza University of Rome, *How to track deterministically moving objects using a binary sensor network*.
- December 11, Nikhil Bansal, IBM Research, *Degree bounded network design*.

In addition, DIS organizes a series of seminars in cooperation with the Department of Computer Science (DI). Below is the list of the seminars of the series.

- January 21 at DIS, Filippo Menczer, University of Indiana, *The web click network*.
- February 4 at DIS, Marie-France Sagot, Laboratoire de biometrie et biologie evolutive, Li-one, *Open combinatorial/graph problems in computational biology*.
- February 18 at DI, Eli Upfal, Brown University, *The hiring problem and lake wobegon strategies*.
- March 3 at DIS, Stefan Dziembowski, Sapienza, University of Rome, *How to do cryptography on non-trusted machines*.
- March 31 at DI, Vincenzo Bonifaci, Sapienza, University of Rome, *Budgeted matching and budgeted matroid intersection via the gasoline puzzle*.
- April 21 at DI, Flavio D'Alessandro, Sapienza, University of Rome, *A survey of the Cerny conjecture*.
- May 12 at DIS, Xiaotie Deng, University of Hong Kong, *Sales of clicks and Auction theory*.
- May 26 at DIS, Ravi Kumar, Yahoo! Research, *Structural properties of online social networks*.
- June 9 at DI, Andrzej Pelc, University of Quebec, *Algorithmic aspects of radio communication*.
- October 27 at DIS, Andrea Clementi, University of Rome Tor Vergata, *Flooding Time in Edge-Markovian Dynamic Graphs*.
- November 10 at DIS, Pierre Fraigniaud, CNRS and University Paris Diderot, *Navigability Emergence in Social Networks*.
- November 17 at DIS, Aris Anagnostopoulos, DIS, Sapienza University of Rome *Influence and Correlation in Social Networks*.

## 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 analysis of combinatorial algorithms and data structures for problems arising in modern Computer Systems and Networks, and in applications related to complex resource management problems. In this general framework, emphasis is put on the design of efficient data structures and algorithms for massive data sets. In particular we concentrate on:

- Combinatorial algorithms and data structures;
- Algorithms for very large data sets;
- Algorithms for optimization and games;
- Web algorithmics and data mining.

The AE group is currently cooperating with several prestigious research institutions: Max Planck für Informatik (Saarbrücken, Germany), University of Paderborn (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).

In 2008 the AE group was involved in the following research projects: EU Contract 001907 "Dynamically Evolving Large Scale Information Systems" (DELIS); EU/IST Integrated Project IP-FP6-015964 AEOLUS, "Algorithmic Principles for Building Efficient Overlay Computers"; EU Project ARRIVAL: "Algorithms for Robust and online Railway optimization: Improving the Validity and reliability of Large scale systems"; EU Project PANORAMA; "Coordination Action for the Pervasive Adaptation"; EU COST project 293 GRAAL; MIUR National Project MAINSTREAM: "Algoritmi per strutture informative di grandi dimensioni e data streams"; MIUR Firb RBIN047MH9 project: international Italian-Israelian cooperation.

#### *Group members*

*Faculty members:* Giorgio AUSIELLO, Luca BECCHETTI, Fabrizio D'AMORE, Camil DEMETRESCU, Stefano LEONARDI, Alberto MARCHETTI-SPACCAMELA, Umberto NANNI, Andrea VITALETTI.

*Post-docs:* Aris ANAGNOSTOPOULOS, Vincenzo BONIFACI, Luigi LAURA, Andrea RIBICHINI, Fabiano SARRACCO, Piotr SANKOWSKI.

*PhD students:* Ilaria BORDINO, Ugo COLESANTI, Lorenzo BERGAMINI, Luca FILIPPONI.

*Visitors:* Pauli MIETTINEN, Helsinki University of Technology (TKK), December 2007 - March 2008; Mohit SINGH, Carnegie Mellon University, December 2007 - January 2008.

**Combinatorial algorithms and data structures.** Our focus was on incremental algorithms for query answering in connectivity problems and for feasibility testing in resource allocation in multiprocessor scheduling.

[6] proposes polynomial oracles to answer queries about the shortest path length among given vertex pairs, possibly under node or link failures.

[7] proposes a general framework for casting fully dynamic transitive closure into the problem of reevaluating polynomials over matrices. [23] proposes the first fully dynamic algorithm for computing the characteristic polynomial of a matrix

In [15] the authors devise the first constant-approximate feasibility test for sporadic multiprocessor real-time scheduling.

**Algorithms for very large data sets.** We have studied memory and computationally efficient algorithms for mining problems in very large networks.

[27] proposes algorithms for computing small stretch spanners in the streaming model, while [26] reports the results of the first computational study of graph spanner algorithms in a streaming setting.

[29] considers several variations of the shortest path problem in a data stream setting and studies trade-offs between memory and computational resources required to solve the problems addressed.

Finally, [11] considers the problem of the accurate estimation of the local clustering coefficient on large graphs in a semi-streaming setting.

**Algorithms for optimization and games.** We considered optimization problems arising in network design, routing and resource allocation.

[13] proposes the first polynomial-time approximation schemes for maximum-weight matching and maximum-weight matroid intersection with additional budget constraints.

[14], [17], [28] and [18] study energy efficient routing and aggregation strategies in sensor networks under latency constraints.

[1], [2], and [3] consider the problem of devising efficient on-line routing strategies under limited clairvoyance or when restrictions on the input apply.

Other contributions consider game-theoretic and stochastic settings. [10] considers the complexity of Nash equilibria in win-lose bimatrix games, [16] investigates the impact of Stackelberg routing on the price of anarchy, while [10] considers a game-theoretical variant of the Steiner forest problem. Stochastic aspects of network design and resource allocation problems are considered in [25] and [24].

**Web algorithmics and data mining.** We considered graph and data mining problems spanning different areas, from Information retrieval to Biology.

[19] proposes and analyzes algorithmic techniques to mine frequent patterns in complex networks, while [8] provides an in-depth experimental study of the self-similarity structure of the Web graph. [20] studies the temporal evolution of large Web snapshots.

[9] provides a theoretical study of similarity and stability properties of prominent Web ranking algorithms. [4] proposes link-based techniques for the automatic detection of pathological forms of search engine optimization, while [22] applies similar techniques to trust management in social networks.

[12] investigates the use of fully decentralized recommendation techniques in pervasive systems of small devices with limited capabilities.

[21] presents the first exact method for the problem of finding a minimal precursor set in a metabolic network, an important problem arising in Computational biology.

## Journals

- [1] Ausiello G., Allulli L., Bonifaci V. and Laura L. On the Power of Lookahead in On-line Server Routing Problems. *Theoretical Computer Science*, **408**(2–3), pp. 116–128, 2008.
- [2] Ausiello G., Bonifaci V. and Laura L. The on-line asymmetric traveling salesman problem. *Journal of Discrete Algorithms*, **6**(2), pp. 290–298, 2008.
- [3] Ausiello G., Bonifaci V. and Laura L. The On-Line Prize Collecting Traveling Salesman Problem. *Information Processing Letters*, **107**(6), pp. 199–204, 2008.
- [4] Becchetti L., Castillo C., Donato D., Baeza-Yates R. and Leonardi S. Link analysis for web spam detection. *ACM Transactions on the Web (TWEB)*, **2**(1), pp. 1–42, 2008.
- [5] Bonifaci V., Di Iorio U. and Laura L. The complexity of uniform Nash equilibria and related regular subgraph problems. *Theoretical Computer Science*, **401**(1–3), pp. 144–152, 2008.
- [6] Demetrescu C., Thorup M., Chowdhury R. A. and Ramachandran V. Oracles for distances avoiding a failed node or link. *SIAM Journal on Computing*, **37**(5), pp. 1299–1318, 2008.
- [7] Demetrescu C. and Italiano G. F. Maintaining Dynamic Matrices for Fully Dynamic Transitive Closure. *Algorithmica*, **51**(4), pp. 387–427, 2008.
- [8] Donato D., Leonardi S., Millozzi S. and Tsaparas P. Mining The Inner Structure of the Web Graph. *Journal of Physics A: Mathematical and Theoretical*, **41**(22), pp. 224017–12pp, 2008.
- [9] Donato D., Leonardi S. and Tsaparas P. Stability and Similarity of Link Analysis Ranking Algorithms. *Internet Mathematics*, **3**(4), pp. 445–473, 2008.
- [10] Koenemann J., Leonardi S., Schaefer G. and van Zwam S. H. M. A group-strategyproof cost sharing mechanism for the steiner forest game. *SIAM Journal on Computing*, **37**(5), pp. 1319–1341, 2008.

## Conference proceedings

- [11] Becchetti L., Boldi P., Castillo C. and Gionis A. Efficient Semi-Streaming Algorithms for Local Triangle Counting in Massive Graphs. *Proceedings of the 14th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (KDD)*, pp. 16–24, 2008.
- [12] Becchetti L., Colesanti U., Marchetti-Spaccamela A. and Vitaletti A. Self-Adaptive Recommendation Systems: Models and Experimental Analysis. *Proceedings of the Second IEEE International Conference on Self-Adaptive and Self-Organizing Systems*, pp. 479–480, 2008.
- [13] Berger A., Bonifaci V., Grandoni F. and Schaefer G. Budgeted matching and budgeted matroid intersection via the gasoline puzzle. *Proc. 13th Conf. on Integer Programming and Combinatorial Optimization (IPCO '08)*, pp. 273–287, 2008.
- [14] Bonifaci V., Korteweg P., Marchetti-Spaccamela A. and Stougie L. Minimizing flow time in the wireless gathering problem. *Proc. 25th Symposium on Theoretical Aspects of Computer Science (STACS '08)*, pp. 109–120, 2008.
- [15] Bonifaci V., Marchetti-Spaccamela A. and Stiller S. A constant-approximate feasibility test for multiprocessor real-time scheduling. *Proc. 16th European Symposium on Algorithms (ESA '08)*, pp. 210–221, 2008.
- [16] Bonifaci V., Harks T. and Schaefer G. Stackelberg routing in arbitrary networks. *Proc. 4th Workshop on Internet and Network Economics (WINE '08)*, pp. 239–250, 2008.

- [17] Bonifaci V., Korteweg P., Marchetti-Spaccamela A. and Stougie L. Minimizing Average Flow Time in Sensor Data Gathering. *Algorithmic Aspects of Wireless Sensor Networks, Fourth International Workshop, ALGOSENSORS 2008*, pp. 18–29, 2008.
- [18] Bonifaci V., Korteweg P., Marchetti-Spaccamela A. and Stougie L. The distributed wireless gathering problem. *Proc. 4th Conf. on Algorithmic Aspects in Information Management (AAIM '08)*, pp. 72–83, 2008.
- [19] Bordino I., Donato D., Gionis A. and Leonardi S. Mining large networks with subgraph counting. *Proceedings of the Eighth IEEE International Conference on Data Mining (ICDM 2008)*, pp. 737–742, 2008.
- [20] Bordino I., Boldi P., Donato D., Santini M. and Vigna S. Temporal Evolution of the UK Web. *ADN-ICDM 2008 Workshop on Analysis of Dynamic Networks*, 2008.
- [21] Couttret L., Milreu Vieira P., Acuna V., Marchetti-Spaccamela A., Viduani Martinez F., Sagot M. F. and Stougie L. Enumerating Precursor Sets of Target Metabolites in a Metabolic Network. *Proc. Algorithms in Bioinformatics, 8th International Workshop, WABI 2008, Proceedings. LNCS vol 5251 Springer 2008*, pp. 233–244, 2008.
- [22] Donato D., Leonardi S. and Panicia M. Combining Transitive Trust and Negative Opinions for better Reputation Management in Social Networks. *In Proceedings of SNAKDD 2008: ACM KDD Workshop on Social Network Mining and Analysis*, 2008.
- [23] Frandsen G.S. and Sankowski P. Dynamic Normal Forms and Dynamic Characteristic Polynomial. *Proceedings of the 35th International Colloquium on Automata, Languages and Programming (ICALP 2008)*, pp. 434–446, 2008.
- [24] Garg N., Gupta A., Leonardi S. and Sankowski P. Stochastic Analyses for Online Combinatorial Optimization Problems. *Proceedings of the Nineteenth Annual ACM-SIAM Symposium on Discrete Algorithms, (SODA 2008)*, pp. 942–951, 2008.
- [25] Grandoni F., Gupta A., Leonardi S., Miettinen P., Sankowski P. and Singh M. Set Covering with Our Eyes Closed. *Proceedings of the 49th Annual Symposium on Foundations of Computer Science (FOCS 2008)*, pp. 347–356, 2008.

### Submitted papers, technical reports and others

- [26] Ausiello G., Demetrescu C., Franciosa P. G., Italiano G. F. and Ribichini A. Graph Spanners in the Streaming Model: an Experimental Study. *Algorithmica*, 2008. Appeared online: <http://www.springerlink.com/content/v2160k27r0688146/>.
- [27] Ausiello G., Franciosa P. G. and Italiano G. F. Small Stretch (alpha, beta)-Spanners in the Streaming Model. *Theoretical Computer Science*, 2008. Special Issue in Honour of Burkhard Monien, to appear.
- [28] Becchetti L., Korteweg P., Marchetti-Spaccamela A., Skutella M., Stougie L. and Vitaletti A. Latency Constrained Aggregation in Sensor Networks. *ACM Transactions on Algorithms*, 2008. To appear.
- [29] Demetrescu C., Finocchi I. and Ribichini A. Trading off space for passes in graph streaming problems. *ACM Transactions on Algorithms*, 2008. To appear.

### 3.1.2 Artificial Intelligence

The Artificial Intelligence Research Group at DIS carries on fundamental and applied research and serves as the centre of most of the AI related research occurring at Sapienza University through a series of activities, colloqui, forums and presentations. Leading members of the Computer and System Sciences Department, in conjunction with researchers, graduate students and undergraduates through various activities, seek to stimulate and promote AI research at Sapienza. Recognitions of achievements of the group activities are reported below.

*Awards* Prof. Luigia Carlucci Aiello has been awarded the *Donald E. Walker Distinguished Service Award* "for her substantial contributions and extensive service to the field of Artificial Intelligence throughout her career" by IJCAI. Prof. Daniele Nardi, Dr. Luca Iocchi and Dr. Amos Vittorio Ziparo have been awarded the *Best Robotics Demo Award* at the Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS2008). Matteo Leonetti (PhD student) has been awarded the "Premio Tesi di Laurea" by Accenture. Letizia Marchegiani (PhD student) has been awarded the "Premio Tesi di Laurea" by AICA (Roma Section).

A brief summary of the areas of research focused upon by members of the Artificial Intelligence Group at DIS is provided below.

- Complexity of Reasoning
- Constraint-based Architectures for Planning and Scheduling
- Computer Vision, Perception and Cognitive Robotics
- Multi-robot and multi-agent systems
- Robotic Navigation, Learning and State Estimation
- Constraint modelling and programming
- Computer Graphics

*Research Projects* Project *Viewfinder* "Vision and Chemi-resistor Equipped Web-connected Finding Robots" (IST-045541-VIEW-FINDER) a FP6 funded project developing an autonomous robotic system to establish ground safety in the event of a fire. ALCOR LAB. Within the project two IARP/EURON Workshops on Robotics for Risky Interventions and Environmental Surveillance have been organized (RISE 2008 and RISE 2009) and one Demo at BEAUVECHAIN airbase.

Contracts with Galileo Avionica (a Finmeccanica associate): "Studio relativo alla stabilizzazione elettronica di immagini provenienti da un sensore IR" concerning the development of image stabilization techniques for camera mounted on aerial vehicles. ALCOR LAB; "FLIR/OVS", concerning the sensorial fusion between a laser range finder and a infrared camera, for an obstacle avoidance system. ALCOR LAB.

Contract with Alenia-Alcatel: "GAPACOM: Sistema satellitare terra/bordo basato sullo studio di un payload NAVCOM innovativo da imbarcare sui satelliti GALILEO". ROCOCO Lab.

*Group members*

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

*Post-docs:* Toni MANCINI, Vittorio Amos ZIPARO.

*PhD Students:* Anna BELARDINELLI, Domenico BLOISI, Daniele CALISI, Andrea CARBONE, Antonella CHIRICHIELLO, Marco FRATARCANGELI, Matteo LEONETTI, Letizia MARCHEGANI, Luca MARCHETTI, Stefano MARRA, Alessio PASCUCCI, Fabio PATRIZI, Matia PIZZOLI, Gabriele RANDELLI, Giuseppe Paolo SETTEMBRE, Gian Diego TIPALDI, Giorgio UGAZIO.

**Complexity of reasoning** Efficiency of AI systems is important for their success, as it is important in all engineering projects. If we are to use logic as the major tool for Knowledge Representation and Reasoning we have to deal with computational aspects. During the year 2008, the AI group has 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 the study of the redundancy of theories in propositional and nonmonotonic logics [5][6].

**Robotic navigation, learning and state estimation** Robotic Navigation, Learning and State Estimation are basic functionalities for intelligent mobile robotic systems. In this context we have addressed motion planning with uncertainty [22], motion planning for tracked robots [19], motion planning for a segway dynamically balanced robot [32], and defined a set of benchmark problems for performance evaluation [36]. Learning methods are often used to improve performance in the applications. In [23], we have analysed various layered learning methods for a soccer robotic task. Finally, an approach to improve state estimation and tracking in distributed systems using reliability of information sources has been proposed in [25], while in [21] we presented an efficient algorithm for global localization.

**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 problem solving [34], context domain design of robotics systems [3], cooperative situation assessment [31] and coordination of robot teams [33]. Several case studies based on UGVs have been addressed in the following application domains: rescue robotics [18, 24], surveillance [20] and robotic soccer [27, 28]. The implemented systems are based on OpenRDK [16, 17], a software framework for robotic applications. We have also studied the possibility of using teams of mini and micro-UAVs for surveillance applications. We organized a workshop on this topic [10] and presented a technique for autonomous hovering for a quadrotor [13].

**Computer vision, perception and cognitive robotics** Research in this area spans from theoretical aspects of pattern recognition to shape and multiple view perception, visual attention and cognitive modelling of artificial agents. Multi-calibration in real time of the human eyes with two pairs of cameras has been proposed in [26] the obtained online calibration for the gaze machine has been used to study different clustering strategies in [1, 8, 14]. New approaches to have been explored in [30] and segmentation and data clustering with ReK-means has been proposed in [15]. In [4] a control architecture for attentive exploration in unstructured environments has been proposed.

**Constraint modelling and programming** Many Constraint Satisfaction Problems (CSPs) coming from real-life applications exhibit “structural” properties that distinguish them from random instances. In [2] we provide a unifying theoretical framework encompassing most of the properties known, both in CSP and other fields literature, and propose two new key properties that subsume all the others. In [35] we show how the whole framework can be elegantly generalized to a different formalism (QCSP) for modelling problems beyond NP. Finally, in [7] exploitation of several (higher-level) structural properties of CSP have been experimentally evaluated on several benchmarks and with solvers based on different technologies. This allowed us to better understand the best modelling and reformulation practices, and discover effective synergies among them.

**Computer graphics** The Computer Graphics group continued its investigation of novel physically-based animation methods. Such a task involves several design phases, from the mathematical modelling of the mechanical laws governing the motion of the real scene, to their discretization and numerical integration. During 2008, we further refined and expanded the framework started in 2007 adding the support for muscles, better integration methods and the (partial) porting of the framework to the Android operating system. The resulting virtual model of the scene can be used to synthesize realistic animation and for planning purposes. All of these new lines of research have not yet produced new publications during 2008, we expect to publish the most relevant results during 2009.

## Journals

- [1] Belardinelli A., Pirri F., and Carbone A. Gaze motion clustering in scan path estimation. *Cognitive Processing*, 9:269–282, 2008.
- [2] Bordeaux L., Cadoli M., and Mancini T. Exploiting fixable, substitutable and determined values in constraint satisfaction problems. *Journal of Artificial Intelligence Research*, 32:607–629, 2008.
- [3] Calisi D., Iocchi L., Nardi D., Scalzo C. M., and Ziparo V. A. Context-based design of robotic systems. *J. RAS Special Issue on Semantic Knowledge in Robotics*, 56:992–1003, November 2008.
- [4] Carbone A., Finzi A., Orlandini A., and Pirri F. Model-based control architecture for attentive robots in rescue scenarios. *Autonomous Robots*, 28:87–120, 2008.
- [5] Liberatore P. Redundancy in logic II: 2CNF and Horn propositional formulae. *Artificial Intelligence*, 172(2–3):265–299, 2008.
- [6] Liberatore P. Redundancy in logic III: Non-monotonic reasoning. *Artificial Intelligence*, 172(11):1317–1359, 2008.
- [7] Mancini T., Cadoli M., Micaletto D., and Fabio Patrizi. Evaluating ASP and commercial solvers on the CSPLib. *Constraints*, 13(4), 2008.

## Articles in books

- [8] Belardinelli A., Pirri F., and Carbone A. Motion saliency maps from spatiotemporal filtering *Attention In Cognitive Systems.*, volume LNAI 5395, pages 112–123. Springer, NLD, 2008.
- [9] Murphy R. R., Tadokoro S., Nardi D., Jacoff A., Fiorini P., Choset H., and Erkmen A. M. *Springer Handbook of Robotics*, chapter Search AND Rescue Robotics, pages 1151–1173. Springer Verlag, 2008.

## Books

- [10] Iocchi L. and Nardi D. (Eds.). Proceedings of workshop on mini and micro uav for security and surveillance. In *Workshop Proceedings of International Conference on Simulation, Modeling and Programming for Autonomous Robots (SIMPAN)*, 2008.
- [11] Iocchi L. and Sorrenti D. G., editors. *Proceedings of the VISAPP International Workshop on Robotic Perception*, Funchal, Madeira, Portugal, January 2008. INSTICC Press.
- [12] Lesperance Y., Lakemeyer G., Peters J., and Pirri F. Proceedings of the 6th international cognitive robotics workshop. pages 1–96. IOS press, 21-22 Luglio 2008.

## Conference proceedings

- [13] Angeletti G., Pereira Valente J. R., Iocchi L., and Nardi D. Autonomous indoor hovering with a quadrotor. In *In Proc. of Workshop on Mini and Micro UAV for Security and Surveillance (CD-ROM Proceedings)*, 2008.
- [14] Belardinelli A., Pirri F., and Carbone A. Motion saliency maps from spatiotemporal filtering. In *WAPCV 2008*, GRC, 12 May 2008.
- [15] Bloisi D. D. and Iocchi L. Rek-Means: A k-Means Based Clustering Algorithm. In *Computer Vision Systems, 6th International Conference (ICVS 2008)*, LNCS 5008, pages 109–118, 2008.
- [16] Calisi D., Censi A., Iocchi L., and Nardi D. OpenRDK: a modular framework for robotic software development. In *In Proc. of Int. Conf. on Intelligent Robots and Systems (IROS)*, pages 1872–1877, September 2008.
- [17] Calisi D., Censi A., Iocchi L., and Nardi D. OpenRDK: a framework for rapid and concurrent software prototyping. In *In Proc. of Int. Workshop on System and Concurrent Engineering for Space Applications (SECESA)*, November 2008.
- [18] Calisi D., Iocchi L., Nardi D., Scalzo C. M., and Ziparo V. A. Contextual navigation and mapping for rescue robots. In *IEEE International Workshop on Safety, Security & Rescue Robotics (SSRR 2008)*, 2008.
- [19] Calisi D., Nardi D., Ohno K., and Tadokoro S. A semi-autonomous tracked robot system for rescue missions. In *Proc. of Int. Conf. on Instrumentation, Control and Information Technology (SICE)*, pages 2066–2069, 2008.
- [20] Canu S., Delle Fave F. M., Iocchi L., Nardi D., and Ziparo V. A. A decentralized approach to cooperative situation assessment in multi-robot systems. In *Proc. of IROS'08 Workshop on Multi-Competence Adaptation in Robotics and A-life*, 2008.
- [21] Censi A., Calisi D., De Luca A., and Oriolo G. A bayesian framework for optimal motion planning with uncertainty. In *Proc. of the IEEE Int. Conference on Robotics and Automation (ICRA)*, pages 1798–1805, May 2008.
- [22] Censi A. and Tipaldi G.D. Lazy localization using the frozen time smoother. In *Proc. of IEEE International Conference on Robotics and Automation (ICRA)*, 2008.
- [23] Cherubini A., Giannone F., and Iocchi L. Layered learning for a soccer legged robot helped with a 3D simulator. In U. Visser, F. Ribeiro, T. Ohashi, and F. (Eds.) Dellaert, editors, *RoboCup 2007: Robot Soccer World Cup XI*, LNAI 5001, pages 385–392. Springer, 2008.
- [24] La Cesa S., Farinelli A., Iocchi L., Nardi D., Sbarigia M., and Zaratti M. Semi-autonomous coordinated exploration in rescue scenarios. In U. Visser, F. Ribeiro, T. Ohashi, and F. (Eds.) Dellaert, editors, *RoboCup 2007: Robot Soccer World Cup XI*, pages 286–293. Springer, July 2008.

- [25] Marchetti L., Nobili D., and Iocchi L. Improving tracking by integrating reliability of multiple sources. In *Proc. of 11th International Conference on Information Fusion*, 2008.
- [26] Marra S. and Pirri F. Eyes and cameras calibration for 3d world gaze detection. In *International Conference on Computer Vision (ICVS)*, volume LNCS, pages 216–227, NLD, May 2008. Springer.
- [27] Palamara P.F., Ziparo V. A., Iocchi L., Nardi D., Lima P., and Costelha H. A robotic soccer passing task using Petri net plans. In *Proc. of 7th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2008)*, pages 1711–1712, May 2008.
- [28] Palamara P.F., Ziparo V. A., Iocchi L., Nardi D., and Lima P. Implementation of joint commitment theory through Petri net plans. In *RoboCup Symposium 2008*, July 2008.
- [29] Pellegrini S., Schindler, and Nardi D. A generalization of the icp algorithm for articulated bodies. In *British Machine Vision Conference*, September 2008.
- [30] Pirri F. and Pizzoli M. Combining appearance and behavioural cues for the purpose of person recognition. In *Proceedings of the Sixth International Cognitive Robotics Workshop*, pages 81–88. IOS Press, 21-22 July 2008.
- [31] Settembre G. P., Scerri P., Farinelli A., Sycara K., and Nardi D. A decentralized approach to cooperative situation assessment in multi-robot systems. In *Proc. of 7th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS-08)*, pages 31–38, May 2008.
- [32] Takeuchi E., Calisi D., Ohno K., Tadokoro S., Igarashi H., Kinjo T., Takamori T., and Matsuno F. Development of RTCs for mobile robots with autonomy and operability - report 2: Obstacle detection modules. In *Proc. of 26th Annual Conf. of the Robotics Society of Japan (RSJ)*, pages 1F3–08, 2008. in Japanese.
- [33] Ziparo V.A., Iocchi L., Nardi D., Palamara P.F., and Costelha H. PNP: A formal model for representation and execution of multi-robot plans. In *Proc. of 7th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2008)*, pages 79–86, May 2008.

#### **Ph.D. theses**

- [34] Ziparo V. A. *Robot Teams for Multi-Objective Tasks*. PhD thesis, Dipartimento di Informatica e Sistemistica Antonio Ruberti, Sapienza Università di Roma, 2008.

#### **Submitted papers, technical reports and others**

- [35] Bordeaux L., Cadoli M., and Mancini T. Generalizing consistency and other constraint properties to quantified constraints.
- [36] Calisi D., Iocchi L., and Nardi D. A unified benchmark framework for autonomous Mobile robots and Vehicles Motion Algorithms (MoVeMA benchmarks). RSS Workshop on Experimental Methodology and Benchmarking, Zurich, Switzerland, 2008.

### **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.

### Group members

*Faculty members* Roberto BALDONI, Luca BECCHETTI, Roberto BERARDI, Stefano LEONARDI, Alberto MARCHETTI-SPACCAMELA, Andrea VITALETTI.

*PhD students* Adnan NOOR MIAN, Ugo COLESANTI, Lorenzo BERGAMINI, Luca FILIPPONI.

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 "Wireless Local Area Network" (WWLAN); EU Contract 001907 "Dynamically Evolving Large Scale Information Systems" (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 random walk protocol for ad hoc wireless networks. The protocol is designed to deal with node mobility. The work described in [7] shows the benefit of bias on random. Through extensive simulations on square grid topology we show that the proposed biasing strategy is most cost effective in searching, most scalable, least affected by neighbor density, and most effective in replicated services scenarios among the compared strategies.

Finally, in [7] we consider RFID technology as an application to robots with low capabilities that can learn information and instructions from such a devices, synchronies with other robots in the area, and finally carry out a cooperative task.

**Sensor networks** In [1, 2, 3, 4] we address the problem of data gathering in a wireless network using multihop communication; our main goal is the analysis of simple algorithms suitable for implementation in realistic scenarios. We study the performance of distributed algorithms, which use limited form of local coordination, and we consider objective functions such as minimizing average and maximum flow time and maximum and average completion time of data packets. The assessment of environmental pollution levels is a complex and expensive task that public administration and often also private entities are willing or forced to take over. Focusing on the assessment of environmental noise pollution in urban areas, we provide qualitative considerations and experimental results to show the feasibility of wireless sensor networks to be used in this context [5, 8].

### Journals

- [1] Bonifaci V., Korteweg P., Marchetti-Spaccamela A., Stougie L. An approximation algorithm for the wireless gathering problem. *Oper. Res. Lett.*, 36(5):605–608, 2008.

### Conference proceedings

- [2] Bonifaci V., Korteweg P., Marchetti-Spaccamela A. Minimizing flow time in the wireless gathering problem. *STACS 2008, 25th Annual Symposium on Theoretical Aspects of Computer Science, Bordeaux, France, February 21-23, 2008, Proceedings*, volume 08001 of *Dagstuhl Seminar Proceedings*. Internationales Begegnungs- und Forschungszentrum fuer Informatik (IBFI), Schloss Dagstuhl, Germany, 2008, pages 109–120.
- [3] Bonifaci V., Korteweg P., Marchetti-Spaccamela A., Stougie L. The distributed wireless gathering problem. *Algorithmic Aspects in Information and Management, 4th International Conference, AAIM 2008, Shanghai, China, June 23-25, 2008. Proceedings*, volume 5034 of *Lecture Notes in Computer Science*. Springer, 2008, pages 72–83.
- [4] Bonifaci V., Korteweg P., Marchetti-Spaccamela A., Stougie L. Minimizing average flow time in sensor data gathering. *Algorithmic Aspects of Wireless Sensor Networks, Fourth International Workshop, ALGOSENSORS 2008, Reykjavik, Iceland, July 2008. Revised Selected Papers*, volume 5389 of *Lecture Notes in Computer Science*. Springer, 2008, pages 18–29.
- [5] Filipponi L., Santini S., Vitaletti A. Data collection in wireless sensor networks for noise pollution monitoring. *Distributed Computing in Sensor Systems, 4th IEEE International Conference, DCOSS 2008, Santorini Island, Greece, June 11-14, 2008, Proceedings*, volume 5067 of *Lecture Notes in Computer Science*. Springer, 2008, pages 492–497.
- [6] Mian A.N., Beraldi R., Baldoni R. A robust and energy efficient protocol for random walk in ad hoc networks with IEEE 802.11. In *22nd IEEE International Symposium on Parallel and Distributed Processing, IPDPS 2008*, pages 1–8, Miami, Florida USA, April 14-18, 2008 IEEE
- [7] Mian, A.N., Baldoni, R., Beraldi, R. An Efficient Biasing Strategy for Random Walk in Wireless Ad Hoc Networks. In *International Wireless Communications and Mobile Computing Conference, 2008. IWCMC '08* pages: 1087 - 1092, 6-8 August, Crete Island, Greece, IEEE
- [8] Santini S., Ostermaier B., Vitaletti A. First experiences using wireless sensor networks for noise pollution monitoring. In *REALWSN '08: Proceedings of the workshop on Real-world wireless sensor networks*, pages 61–65, New York, NY, USA, 2008. ACM.
- [9] Zecca G., Couderc P., Banatre M., Beraldi R. Cooperation in a swarm of robots using RFID landmarks. In *International Workshop on RObotic and SEnsors Environments, ROSE 2008*, pages 1087–1092 Ottawa, Ontario, Canada 17-18 October 2008 IEEE

#### 3.1.4 Data and Knowledge Bases

The research activities of the group working on Data and Knowledge Bases are to the greatest extent oriented towards three main areas, namely, *Advanced Data Management*, *Knowledge Representation and Reasoning*, and *Human Computer Interaction*. More specifically, for each area the following topics are considered.

- Advanced Data Management:
  - Data Integration and Exchange, i.e., virtual integration, where main focus is on processing queries posed to a global reconciled schema connected to data sources through mappings, and materialized integration, where main focus is on computing global (aka target) instances from a source instance;
  - Ontology-based Information Systems, i.e., studying methods and techniques to design and develop information systems relying on ontologies and exploiting reasoning mechanisms on ontologies;

- View-based Query Processing, i.e., processing a query posed to a database only on the basis of the information on a set of views over such database;
- Data Quality and Data Cleaning, i.e., defining and measuring the quality of data and improving the quality of data through data cleaning techniques, specifically record linkage and object identification techniques.
- Knowledge Representation and Reasoning:
  - 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;
  - Semantic Web, i.e., design and development of semantic-based techniques for knowledge representation, reasoning, and data access in the Semantic Web.
- Human Computer Interaction:
  - 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.
  - UCD-Agile methodology, i.e., the approach to integrate user centred design (UCD) principles and techniques in agile software development processes and environments.

In 2008 group members have been involved in several research projects, including the following: FP6-2005-IST-5-034749 WORKPAD; EU Project FP7-224332 SM4All; EU project IFP7-ICT-2007-C-FET-Open VISMMASTER CA; MIUR FIRB 2005 project TOCAI.IT (Tecnologie Orientate alla Conoscenza per Aggregazioni di Imprese in Internet), where the group participates as member of CINI (Consorzio Interuniversitario Nazionale per l'Informatica) ; EU FET project FP6-7603 TONES (Thinking ONtologiES). Furthermore, a research contract with C.M. SISTEMI has been established, which is focused on the study of methods and languages for representing and designing ontologies.

The group members are:

*Faculty members:* Tiziana CATARCI, Giuseppe DE GIACOMO, Domenico LEMBO,  
Maurizio LENZERINI, Riccardo ROSATI, Silvio SALZA, Giuseppe SANTUCCI

*Post-Docs:* Enrico BERTINI, Antonella POGGI, Marco RUZZI

*PhD students:* Claudio CORONA, Domenico Fabio SAVO, Shah Rukh HUMAYOUN, Matteo DI GIOIA

*Visitors:* Carola AIELLO, Monica SCANNAPIECO, Luigi DRAGONE

The research activity is described in the following, by listing work and contributions of group members in each of the above mentioned topics. We point out that such research is addressed in the context of the activities of the DASI-lab (<http://www.dis.uniroma1.it/~dasilab/>).

### Advanced data management

*Data Integration and Exchange.* Mediator-based data integration is the problem of combining the data residing at different heterogeneous sources, and providing a virtual unified view of these data, called *global schema*, which can be queried by the users. Basically adopting the same framework, Data Exchange focuses instead on the problem of materializing the global schema according to the data retrieved from the sources. Both (virtual) data integration and data exchange have been recently studied in the context of a peer-to-peer (P2P) data management, where autonomous systems (peers) export data in terms of their own data schema, and import data from other peers to which they are connected through semantic mappings.

The Data and Knowledge Bases research group is actively involved since several years in research on the above topics, both from a theoretical and a practical point of view. In particular, in the last year two papers focused on the problem of inconsistency management in data integration systems have been produced. In [1], the problem is studied in a P2P context, and 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. A nonmonotonic extension of the logic is proposed that is able to repair mutual inconsistent information flowing from different peers. In [5] query answering over inconsistent data is studied in the simplified setting of relational databases, and optimization issues, well-suited for data integration, are presented.

Data integration in the presence of a global unified view expressed in terms of an ontology has been also the subject of intensive research. This is however, described in the next paragraph.

*Ontology-based Information Systems.* Ontology-based Information Systems are systems in which ontologies are exploited for information management, that is for enabling advanced information and knowledge representation and powerful reasoning mechanisms.

According to this idea, in [11] a tool is presented, called MASTRO-I, for ontology-based data integration. The theoretical basis of MASTRO-I can be found in the extensive work carried out in the field of data integration in the last years, as well as in the investigation carried out by the group in the field of Description Logics (see below). More specifically, In [6] advanced techniques are described that allow one to profitably link databases to ontologies, in order to access data mediated by conceptual representation of the domain of interest. An interesting experimentation of MASTRO-I on real world data is described in [10], whereas a demonstration of the tool, coupled with a state-of the art editor for ontology can be found in [22].

*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, view-based query processing has been studied in a setting in which both the query and the views are issued over a Description Logic ontology, rather than a database schema [13].

*Data quality and data cleaning.* Record linkage is among the most important data quality activities. In open data integration scenarios, a specific feature is related to the unpredictable nature of data that can undergo the record linkage process. One of the most used decision models for record linkage is the probabilistic Fellegi-Sunter model. It is widely debated that the estimation of the parameters of such a model is successful only under some specific restrictions on the distribution of matches and unmatches on the datasets. This assumption does not clearly hold in open data integration scenarios. We are investigating the usage of techniques based on evolutionary computation to perform record linkage in such scenarios ([15, 16]).

Moreover, as a further research topic, we are investigating the relationships between record linkage and privacy. Specifically, in [21] we have studied how to perform record linkage in a

privacy preserving way by considering the tradeoff between the accuracy of data to be privacy-preserved and the risk of privacy violations.

Besides record linkage, a further research issue is related to the characterization of complex distributed systems called “emergent semantics systems” [7].

### Knowledge representation and reasoning

*Description logics.* The goal of the research in Description Logics (DLs) is to study the foundations of class-based knowledge representation formalisms, with regards to both the expressive power and the computational properties of the associated reasoning techniques. In [4], a in-depth investigation on the problem of update at the instance level ontologies specified in the tractable DL *DL-Lite* is carried out. In [12], the use of a powerful form of identification constraints is studied in both an expressive (*ALCQIbreg*) and a tractable DL (*DL-Lite*). In [23] finite model reasoning in *DL-Lite* theories is investigated. In [24] computational properties of systems combining DL ontologies and Datalog rules are studied and new results on this issue are provided. Finally, conjunctive query containment under DL constraints is studied in [2], where algorithms for decidable cases are given, and undecidability of containment of conjunctive queries with inequalities is proved.

*Semantic Web.* 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 [17] a preliminary report is given on DL-Lite extensions for representing and reasoning about meta-level elements, a topic that has strong impact on SW applications, whereas in [14] the relationship between OWL and *DL-Lite* is discussed.

### Human-computer interaction

*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 the research shifted on the emerging field of Visual Analytics, whose goal is to focus on the analysis process that leads to explanation, interpretation and presentation of hidden information in the data, taking advantage of dynamic visualizations. In [9] we present a visual data mining environment intended for Visual Analytics activities. Moreover we continued to work on evaluation problems organizing the ACM BELIV’08 (“BEyond time and errors: novel evaluation methods for Information Visualization”) workshop 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. In this context the design of usable interfaces is a key element for the success of software and devices since physical and cognitive resources are scarce and screen space must be used with care. In the last year we focused our activity on the design of a complete usability and accessibility evaluation methodology for mobile devices which is one of the first attempt to jointly consider these two complementary aspects of interactive systems [26, 8, 27]

*User interfaces to digital libraries.* The research in this area focused on non-conventional access paradigms as the core research advance for defining a user-centered and user requirements-driven support for the design of effective Digital Libraries (DLs) [36]. In particular, we imple-

mented and experimented two access paradigms: catalogue browsing and scatter-gather. Scatter/Gather is one of the most flexible and interactive existing browsing approaches [33]. It clusters documents into topically-coherent groups, and displays summaries to the user. The summaries are composed of topical terms and generally characterise each cluster. Along with topical terms, sometimes document titles are also presented as summaries. After looking at the summaries, the user may select clusters, forming a sub-collection, for iterative examination. The clustering and re-clustering is done on-the-fly, so that different groups are presented depending on the sub-collection chosen. Besides the "Scatter-Gather" access paradigm, another non-conventional access paradigm for DLs is the "catalogue browsing" access paradigm, bringing expertise and design knowledge common in other domains (such e-commerce, e-learning) to the lifecycle of DL development. During the last year, the two access paradigms were implemented in a mobile system equipped with two interchangeable interfaces: a visual one and a vocal one, and tested in a controlled experiment [32, 29].

*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. 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 [3].

*UCD-Agile methodology.* Collecting and analyzing the end users' feedback in an effective and efficient manner is one of the big challengers in software development and is one of the main causes of user centred design (UCD) approach. We provide a methodology for integrating UCD techniques in software development environments to manage user evaluation alongside the process of software development. In [18], we describe the experience, background, and the previous work that our research group have done in both fields: in agile software development processes, and in the application of UCD techniques; both in industry and in academia. Based on our experience, we identified lack of UCD management, which we define for a specific software project as the ability to steer and control the UCD activities within the development of this project, as a tool in software development environments. To fill the identified gap, in [19] a tool is presented for Eclipse development platform to manage UCD activities at the Integrated Development Environment (IDE) level. In [20], we provides the details how the developed tool, named as UEMan, can be used to manage user evaluation alongside the process of software development. The tool is based on our idea that user evaluation should be managed iteratively from within IDE in order to provide high quality user interface. The presented tool can be used for any iteratively-based development process, but best suited for processes with nature of agility.

## Journals

- [1] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., and Rosati R. Inconsistency tolerance in P2P data integration: an epistemic logic approach. *Information Systems*, 33(4):360–384, 2008.
- [2] Calvanese D., De Giacomo G., and Lenzerini M. Conjunctive query containment and answering under description logic constraints. *ACM Trans. on Computational Logic*, 9(3):22.1–22.31, 2008.

- [3] Catarci T., Di Giovanni L., Gabrielli S., Kimani S., and Mirabella M. Scaffolding the design of accessible elearning content: a user-centred approach & cognitive perspective. *Cognitive Processing Journal*, 9:209–216, 2008.
- [4] De Giacomo G., Lenzerini M., Poggi A., and Rosati R. On instance-level update and erasure in description logic ontologies. *J. of Logic and Computation, Special Issue on Ontology Dynamics*, 2008.
- [5] Eiter T., Fink M., Greco G., and Lembo D. Repair localization for query answering from inconsistent databases. *ACM Trans. on Database Systems*, 33(2):10:1–51, 2008.
- [6] Poggi A., Lembo D., Calvanese D., De Giacomo G., Lenzerini M., and Rosati R. Linking data to ontologies. *J. on Data Semantics*, X:133–173, 2008.

### Articles in books

- [7] Aiello C., Catarci C., Ceravolo P., Damiani E., Scannapieco M., and Viviani M. Emergent semantics in distributed knowledge management. In L. Jain, editor, *Evolution of WEB in an Artificial Intelligence Environment*, pages 201–220. Springer-Verlag, 2008.
- [8] Catarci T., Dix A., Gabrielli S., and Kimani S. Designing for tasks in ubiquitous computing: Challenges and considerations. In *Advances in Ubiquitous Computing: Future Paradigms and Directions*. IGI Publishing, 2008.
- [9] Kimani S., Catarci T., and Santucci G. A visual data mining environment. In S. Simoff, M.H.Bohlen, and A. Mazeika, editors, *Visual Data Mining: Theory, Techniques and Tools for Visual Analytics*, pages 331–366. Springer, LNCS State of the Art Surveys, 2008.

### Conference proceedings

- [10] Amoroso A., Esposito A., Lembo D., Urbano P., and Vertucci R. Ontology-based data integration with MASTRO-I for Configuration and Data Management at SELEX sistemi integrati. In *Proc. of the 16th Italian Conf. on Database Systems (SEBD 2008)*, pages 81–92, 2008.
- [11] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., Pogg A., Rosati R., and Ruzzi M. Data integration through *DL-Lite<sub>A</sub>* ontologies. In K.-D. Schewe and B. Thalheim, editors, *Semantics in Data and Knowledge Bases: Postproc. of the Int. Workshop SDKB 2008*, volume 4925 of *Lecture Notes in Computer Science*, pages 26–47. Springer, 2008.
- [12] Calvanese D., De Giacomo G., Lembo D., Lenzerini M., and Rosati R. Path-based identification constraints in description logics. In *Proc. of the 11th Int. Conf. on the Principles of Knowledge Representation and Reasoning (KR 2008)*, 2008.
- [13] Calvanese D., De Giacomo G., Lenzerini M., and Rosati R. View-based query answering over description logic ontologies. In *Proc. of the 11th Int. Conf. on the Principles of Knowledge Representation and Reasoning (KR 2008)*, pages 242–251, 2008.
- [14] Corona C., Di Pasquale E., Poggi A., Ruzzi M., and Savo D. F. When DL-lite met OWL... In *Proc. of the 5th Int. Workshop on OWL: Experiences and Directions (OWLED 2008)*, 2008.
- [15] Cusmai F., Aiello C., Scannapieco M., and Catarci T. Record linkage as a multiobjective optimization problem solved by evolutionary computation. In *ESTEEM'08 - First International Workshop on Emergent Semantics and cooperation in opEn systemEs, In cooperation with the 2nd International Conference on Distributed Event-Based Systems (DEBS08)*, 2008.
- [16] Cusmai F., Aiello C., Scannapieco M., and Catarci T. Earl: an evolutionary algorithm for record linkage. In *6th International Workshop on Quality in Databases, in conjunction with VLDB 2008*, 2008.

- [17] De Giacomo G., Lenzerini M., and Rosati R. Towards higher-order DL-Lite (preliminary report). In *Proc. of the 2008 Int. Work. on Description Logic (DL 2008)*, 2008.
- [18] Dubinsky Y., Catarci T., Humayoun S. R., and Kimani S. Managing user-centred design in agile projects. In *the workshop "Optimizing Agile User-Centred Design" during the 26th CHI Conference (CHI 2008), Florence, Italy, April 5-10, 2008*.
- [19] Dubinsky Y., Humayoun S. R., and Catarci T.. Eclipse plug-in to manage user centred design. In *Proc. of the 1st International workshop on the Interplay between Usability Evaluation and Software Development (I-USED 2008), Pisa, Italy, September 24, 2008*.
- [20] Humayoun S. R., Dubinsky Y., and Catarci T. UEMan: A tool to manage user evaluation in development environments. In *Proc. of the 31st International Conference on Software Engineering (ICSE 2009), Vancouver, Canada, May 16-24, 2009*.
- [21] Inan A., Kantarcioglu M., Bertino E., and Scannapieco M. A hybrid approach to private record linkage. In *Proceedings of the 24th International Conference on Data Engineering (ICDE 2008)*, 2008.
- [22] Pogg A., Rodriguez-Muro M., and Ruzzi M. Ontology-based database access with digmastro and the obda plugin for protégé (demo). In *Proc. of the 4th Int. Work. on OWL: Experiences and Directions (OWLED 2008 DC)*, 2008.
- [23] Rosati R. Finite model reasoning in dl-lite. In *Proc. of the 5th European Semantic Web Conference (ESWC 2008)*, volume 5021 of *Lecture Notes in Computer Science*, pages 215–229. Springer, 2008.
- [24] Rosati R. On combining description logic ontologies and nonrecursive datalog rules. In *Proc. of the 2nd Int. Conf. on Web Reasoning and Rule Systems (RR 2008)*, 2008.

#### **Ph.D. theses**

- [25] Dragone L. *Modeling and Reasoning about Semantic e-services in Cooperative Information Systems*. PhD thesis, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2008.

#### **Submitted papers, technical reports and others**

- [26] Bertini E., Catarci T., Dix A., Gabrielli S., Kimani K., and Santucci G. Appropriating heuristic evaluation for mobile computing. *Int. Journal of Mobile Human-Computer Interaction*, 1(1):20–41, 2009.
- [27] Billi M., Burzagli L., Catarci T., Santucci G., Bertini E., Gabbanin F., and Palchetti E. A unified methodology for the evaluation of accessibility and usability of mobile applications. submitted to *UAIS Journal*, Springer.
- [28] Burnett M., Costabile M. F., Catarci T., de Ruyter B., Tan D. S., Czerwinsky M., and Lund A., editors. *Proceedings of the SIG CHI conference on Human factors in computing systems, CHI 2008, 5-10 April, 2008, Florence, Italy, 2008*.
- [29] Catarci T., Kimani S., Dubinsky Y., and Gabrielli S. Vocal interfaces in supporting and enhancing accessibility in digital libraries. In C. Stephanidis, editor, *The Universal Access Handbook*. CRC Press. To Appear.
- [30] Catarci T. and Miller R. Guest editorial: Special issue on metadata management. *VLDB J.*, 17:1345–1346, 2008.
- [31] Catarci T., Panetto H., and Scannapieco M. Editorial. *Information Systems*, 33:595–596, 2008.

- [32] Dubinsky Y., Kimani S., and Catarci T. The evaluation ontology. In *Handbook of Research on Digital Libraries: Design, Development, and Impact*. IGI Global publication, 2009.
- [33] Dubinsky Y., Kimani S., and Catarci T. Knowledge evolution using digital libraries. In *Handbook of Research on Digital Libraries: Design, Development, and Impact*. IGI Global publication, 2009.
- [34] Lenzerini M. Database theory column: report on pods 2008. *SIGACT News*, 39(3):63–65, 2008.
- [35] Lenzerini M. and Lembo D., editors. *Proceedings of the Twenty-Seventh ACM SIGMOD-SIGACT-SIGART Symposium on Principles of Database Systems, PODS 2008, June 9-11, 2008, Vancouver, BC, Canada*. ACM, 2008.
- [36] Kimani S., Panizzi E., Catarci T., and Antona M. Digital library requirements: A questionnaire-based study. In *Handbook of Research on Digital Libraries: Design, Development, and Impact*. IGI Global publication, 2009.

### 3.1.5 Service Oriented Computing

The Service Oriented Computing area addressed topics both at the theoretical and application-oriented level, in the fields of:

- Service modeling, synthesis and composition;
- Reasoning about actions;
- Process and workflow management;
- Software architectures.

The area comprises several projects, including the following: Progetto MIUR (FIRB 2003) eG4M - eGovernment for Mediterranean Countries; Progetto IST “SemanticGOV”; Progetto IST “WORKPAD”; Progetto IST “SM4All”; IBM gift for “SOC Research”.

The members of the area are:

*Faculty members:* Giuseppe DE GIACOMO, Massimo MECELLA

*Post-Docs:* Antonella POGGI

*PhD students:* Massimiliano DE LEONI, Fabio PATRIZI

*Visitors:* Yves LESPERANCE

Research activity is described in the following, by grouping works and contributions of the area for each of the above mentioned topics. We point out that such research is addressed in the context of the activities of the DASIlab (<http://www.dis.uniroma1.it/~dasilab/>).

**Service modeling, synthesis and 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 service modeling and 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 [2, 1, 11, 8]. Moreover, [14] investigates fundamental decision problems and composition synthesis for Web services commonly found in practice.

The application of services in the specific scenario of the Italian eGovernment initiatives has been presented in [5]. Some issues related to security aspects in services have been addressed in [16].

**Reasoning about actions.** The work on services has produced some foundational results of interest for the AI area of Reasoning about Actions in multi agent systems. Specifically [12], largely inspired by the work on robot ecologies and intelligent spaces, looks at the problem of simultaneously realizing several virtual agents with a specified complex logic, out of a set of available devices. The results show how, exploiting results from LTL synthesis, it is possible to automatically combine dynamically such devices so as that their collective behavior follows that of the concurrent execution of the virtual agents. The work [15] proposes a formal model of planning for agents that operate in a dynamic and incompletely known environment, assuming that both agents' and environment behaviors are formalized by high-level nondeterministic concurrent programs in some agent programming language (APL). The general model can be instantiated, for example, in the situation calculus with programs for the agent and the environment expressed in ConGolog, where it produces a concrete mechanism for conditional planning under incomplete information.

**Process and workflow management.** This 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, 6, 7, 13].

Moreover members of the area have been invited to give a talk on adaptive process management at Progility 2008, in the context of WETICE 2008.

**Architectures.** The paradigm of the Service Oriented Computing (SOC) can be effectively applied in designing and deploying complex architectures. In [3] it has been tailored for designing and developing innovative software infrastructures for supporting collaborative work of human operators in emergency/disaster scenarios.

In [9] the SOC paradigm is applied to embedded systems for specific domotic applications.

In [10] a P2P architecture for live video streaming is presented and evaluated in the large on top of the PlanetLab testbed.

## Journals

- [1] Berardi D., Cheikh F., De Giacomo G., Patrizi F. Automatic Service Composition via Simulation. *International Journal of Foundations of Computer Science*, 19(2): 429-451, 2008.

- [2] Calvanese D., De Giacomo G., Lenzerini M., Mecella M., Patrizi F. Automatic Service Composition and Synthesis: the Roman Model. *IEEE Data Eng. Bull.*, 31(3): 18-22 (2008).
- [3] Catarci T., de Leoni M., Marrella A., Mecella M., Salvatore B., Vetere G., Dustdar S., Juszczak L., Manzoor A., Truong H.L. Pervasive Software Environments for Supporting Disaster Responses. *IEEE Internet Computing*, 12(1): 26-37 (2008).
- [4] de Leoni M., Humayoun S.R., Mecella M., Russo R. A Bayesian Approach for Disconnection Management in Mobile Ad-hoc Networks. *Ubiquitous Computing and Communication Journal*, special issue on Collaborative Pervasive Environments (CPE), ISSN: 1992-8424: 151-162 (2008).

### Conference proceedings

- [5] Baldoni R., Fuligni S., Mecella M., Tortorelli F. The Italian e-Government Enterprise Architecture: A Comprehensive Introduction with Focus on the SLA Issue, Proc. ISAS 2008 - 5th International Service Availability Symposium.
- [6] Battista D., de Leoni M., De Gaetanis A., Mecella M., Pezzullo A., Russo A., Saponaro C. ROME4EU: A Web Service-Based Process-Aware System for Smart Devices, Proc. ICSOC 2008 - 6th International Conference on Service Oriented Computing.
- [7] Bertelli G., de Leoni M., Mecella M., Dean J. Mobile Ad hoc Networks for Collaborative and Mission-critical Mobile Scenarios: a Practical Study, Proc. DMC 2008 - 6th IEEE International Workshop on Distributed and Mobile Collaboration, at WETICE 2008.
- [8] Bonomi S., Colaianni V., Patrizi F., Pozzi D., Russo R., Mecella M. SWSCE - An Automatic Semantic Web Service Composition Engine, Proc. ESTEEM 2008 - 1st International Workshop on Emergent Semantics and cooperation in open systems.
- [9] Catarci T., Cincotti F., de Leoni M., Mecella M., Santucci G. Smart Homes for All: Collaborating Services in a for-All Architecture for Domotics, Proc. CollaborateCom 2008 - 4th International Conference on Collaborative Computing: Networking, Applications and Worksharing.
- [10] Covino F., Mecella M. Design and Evaluation of a System for Mesh-based P2P Live Video Streaming, Proc. MoMM 2008 - 6th International Conference on Advances in Mobile Computing and Multimedia.
- [11] De Giacomo G., Patrizi F., Sardina S. Behavior Composition in the Presence of Failure, Proc. KR 2008 - 11th International Conference on Principles of Knowledge Representation and Reasoning.
- [12] De Giacomo G., Sardina S. Realizing Multiple Autonomous Agents through Scheduling of Shared Devices, Proc. ICAPS 2008 - 2008 International Conference on Automated Planning and Scheduling.
- [13] de Leoni M., Marrella A., Mecella M., Valentini S., Sardina S. Coordinating Mobile Actors in Pervasive and Mobile Scenarios: An AI-based Approach, Proc. COMA 2008 - 2nd IEEE International Workshop on Interdisciplinary Aspects of Coordination Applied to Pervasive Environments: Models and Applications, at WETICE 2008.
- [14] Fan W., Geerts F., Gelade W., Neven F., Poggi A. Complexity and Composition of Synthesized Web Services, Proc. PODS'08 - 28th ACM International Conference on Principles of Database Systems.

- [15] Lesperance Y., De Giacomo G., Ozgovde A.N. A Model of Contingent Planning for Agent Programming Languages, Proc. AAMAS'08 - 7th International Conference on Autonomous Agents and Multiagent Systems.
- [16] Paci F., Ouzzani M., Mecella M. Verification of Access Control Requirements in Web Services Choreography, Proc. SCC 2008 - 2008 IEEE International Conference on Services Computing.

### 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 2008, 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 (Louvain-la-Neuve, 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 Darmstadt (Germany), Univ of Paris VI (France), Cornell Univ. (USA), Technical Univ. of Dresden (Germany), GeorgiaTech (USA), Humboldt Univ. (Germany).

The Distributed Systems group is currently involved in the following research projects: Sm4All (EU-IST), CoMiFin (EU-IST), SOFIA (EU-Artemis JU), eDIANA (EU-Artemis JU), Semantic.gov (EU-IST), ReSIST (EU-IST) 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) and "Implementing the Data Distribution Service specification in wide-area settings" (Selex-SI/Finmeccanica).

*Faculty members:* Roberto BALDONI, Roberto BERARDI, Leonardo QUERZONI.

*Post-docs:* Yann BUSNEL, Giorgia LODI, Alessia MILANI, Sara TUCCI PIERGIOVANNI.

*PhD students:* Silvia BONOMI, Adnan Noor MIAN, Marco PLATANIA, Sirio SCIPIONI.

*Visitors:* Idith KEIDAR, Michel RAYNAL, Ravi PRAKASH, DAVID POWELL.

### Theory of distributed computing

*Theory of Fault-tolerance.* In [2] we introduced a new methodology to design arbitrary failure detectors for distributed protocols.

*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 gave a definition of the eventual connectivity problem for dynamic distributed systems and proposed an algorithm able to build an overlay network satisfying the eventual connectivity specification [11]. A further interesting research dimension in this area is the adaptation, or re-definition, of the basic abstractions and problems characterizing static distributed systems. In this direction, our focus was on the implementability of regular register abstraction [20] and on the solvability of the eventual leader election problem [19, 27]. Finally, in this same area we also investigate

theoretically the problem of distributed coordination of mobile robots with the aim of exploring a graph [6, 1, 5].

*Mobile Ad-hoc and sensor networks.* These systems represent a challenging environment for the deployment of distributed applications. The mobility of nodes (in mobile ad hoc networks) and the scarce resources available to sensors (in sensor networks) dramatically affect the behaviour of processes. For these reason well-known solutions from the theory of static distributed systems cannot be applied without modifications. In this context we studied the problem of anonymous object detection and tracking through binary sensor networks [12, 4, 29]. Moreover, we also studied how shared regular registers can be implemented in a distributed setting represented by a mobile ad-hoc network [17, 18]. Finally, our work was also devoted to identify theoretical bounds for a deterministically reliable geocast primitive applied to a mobile environment [13, 24]. In [14] we presented a random walk protocol for ad hoc wireless networks. The protocol is designed to deal with node mobility. In [2] we presented a new methods to improve random walk behaviour in wireless ad hoc networks. The work described in [15] shows the benefit of bias on random. Through extensive simulations on square grid topology we show that the proposed biasing strategy is most cost effective in searching, most scalable, least effected by neighbor density, and most effective in replicated services scenarios among the compared strategies.

### Peer-to-peer systems

Peer-to-peer (P2P) is today a widely adopted technology as well as a hot research topic. A P2P system is a highly dynamic distributed system with no central administration and where participants act autonomously and collaborate. For these characteristics, a P2P system can reach a potentially infinitely wide scale with a transient population of nodes. Overlay networks have emerged as viable solutions to support P2P applications in an efficient and scalable manner maintaining a satisfactory level of reliability. Our research in this area focused on the investigation of deterministic structures to be used to build structured overlay networks. In particular we concentrate our attention on the family of logarithmic Harary graphs (LHG), by proposing two sets of rules to generate such kind of graphs for an arbitrary number of participants [7, 21]. In this same area we also defined a new distributed algorithm that can be leveraged to reliably store data objects in a P2P system [31]. Finally, we investigated the possibility of implementing mutual exclusion access to shared resources in managed P2P settings implementing quorum systems over Distributed Hash Tables. Our research work [3, 25] managed to reach this goal providing efficient solutions that try to reduce the cost needed to obtain quorums.

### 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 scenario we studied [10, 22] the feasibility of clock synchronization in very large and dynamic settings using techniques inspired from the biological phenomenon of coupled oscillators. These techniques can be applied to a distributed systems to enact self-convergence toward a synchronized clock value among a large set of cooperating peers also in presence of malicious peers [8].

*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 exploration of various advanced clustering techniques aimed at improving the performance of event diffusion mechanisms in large-scale settings [16]. In this same area we also studied the behaviour of industry-grade data distribution service implementations in a wide area setting to outline current limitations of such communication middleware platforms [9]. Finally, in [30] we provided a survey of discovery protocols for mobile ad hoc networks.

### Journals

- [1] Baldoni R., Bonnet F., Milani A., Raynal M. Anonymous graph exploration without collision by mobile robots, *Inf. Process. Lett.*, 109(2): 98-103, 2008.
- [2] Baldoni R., Héлары J-M., Tucci Piergiovanni S. A methodology to design arbitrary failure detectors for distributed protocols, *Journal of Systems Architecture - Embedded Systems Design*, vol. 54, num. 7, pp. 619-637, 2008
- [3] Baldoni R., Jiménez-Peris R., Patino-Martinez M., Querzoni L., Virgillito A. Dynamic quorums for DHT-based enterprise infrastructures, *Journal of Parallel and Distributed Computing*, 68, pp. 1235-1249, 2008.

### Conference proceedings

- [4] Baldoni R., Bertier M., Busnel Y., Kermarrec A., Querzoni L. Suivi et identification de trajectoires sur un reseau de capteurs binaires In Proceedings of Algotel, 2008.
- [5] Baldoni R., Bonnet F., Milani A., Raynal M. Brief Announcement: On the Solvability of Anonymous Partial Grids Exploration by Mobile Robots, In *Proceedings of the 22nd International Symposium on Distributed Computing (DISC)*, 2008
- [6] Baldoni R., Bonnet F., Milani A., Raynal M. On the Solvability of Anonymous Partial Grids Exploration by Mobile Robots, In *Proceedings of the 12th International Conference On Principles Of Distributed Systems (OPODIS)*, 2008.
- [7] Baldoni R., Bonomi S., Querzoni L., Tucci Piergiovanni S. Investigating the Existence and the Regularity of Logarithmic Harary Graphs, In *Proceedings of the 27th IEEE International Symposium on Reliable Distributed Systems (SRDS)*, 2008.
- [8] Baldoni R., Platania M., Querzoni L., Scipioni S. A peer-to-peer filter-based algorithm for internal clock synchronization in presence of corrupted processes, In *Proceedings of the 14th Pacific Rim International Symposium on Dependable Computing (PRDC)*, 64-72, 2008.
- [9] Baldoni R., Querzoni L., Scipioni S. Event-based data dissemination on interadministrative domains: a practical analysis. In *Proceedings of the 12th IEEE International Workshop on Future Trends of Distributed Computing Systems (FTDCS)*, 2008.
- [10] Baldoni R., Querzoni L., Scipioni S., Tucci Piergiovanni S. A theoretical evaluation of peer-to-peer internal clock synchronization, In *Proceedings of the 2nd International Conference on Autonomic Computing and Communication Systems (Autonomics)*, 2008.
- [11] Bonomi S., Tucci Piergiovanni S. Core-based Reconfiguration for Reliable Overlay Networks, In *Proceedings of the 1st International Workshop on Emergent Semantics and cooperation in opEn systEMs (ESTEEM)*, 2008.

- [12] Busnel Y., Querzoni L., Baldoni R., Bertier M., Kermarrec A. On the deterministic tracking of moving objects with a binary sensor network, In *Proceedings of the 4th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS)*, 2008.
- [13] Fernández Anta A., Milani A. Bounds for Deterministic Reliable Geocast in Mobile Ad-Hoc Networks, In *Proceedings of the 12th International Conference On Principles Of Distributed Systems (OPODIS)*, 2008.
- [14] Mian A.N., Beraldi R., Baldoni R. A robust and energy efficient protocol for random walk in ad hoc networks with IEEE 802.11. In *Proceedings of the 22nd IEEE International Symposium on Parallel and Distributed Processing (IPDPS)*, 2008
- [15] Mian A.N., Beraldi R., Baldoni R. An Efficient Biasing Strategy for Random Walk in Wireless Ad Hoc Networks In *Proceedings of the International Wireless Communications and Mobile Computing Conference (IWCMC)*, 2008
- [16] Querzoni L. Interest clustering techniques for efficient event routing in large-scale settings., In *Proceedings of the 2nd International Conference on Distributed Event-Based Systems (DEBS)*, 2008.
- [17] Roy M., Killijian M-O., Tucci-Piergiovanni S., Querzoni L., Bonomi S., Scipioni S., Bonnet F. FADA: Formalisms and Algorithms for Resilient Services Design in Ambient Systems, In *Proceedings of the 7th European Dependable Computing Conference (EDCC)*, Fast Abstracts, 2008.
- [18] Roy M., Bonnet F., Querzoni L., Bonomi S., Killijian M.-O., Powell D. Geo-registers: an abstraction for spatial-based distributed computing. In *Proceedings of the 12nd International Conference On Principles of Distributed Systems (OPODIS)*, 2008.
- [19] Tucci Piergiovanni S., Baldoni R. Brief Announcement: Eventual Leader Election in the Infinite Arrival Message-Passing System Model, In *Proceedings of the 22nd International Symposium on Distributed Computing (DISC)*, 2008

#### **Submitted papers, technical reports and others**

- [20] Baldoni R., Bonomi S., Kermarrec A.M., Raynal M. Implementing a Register in a Dynamic Distributed System, (to appear) in *Proceedings of the 29th IEEE International Conference on Distributed Computing Systems (ICDCS)*, 2009
- [21] Baldoni R., Bonomi S., Querzoni L., Tucci Piergiovanni S. Investigating the Existence and the Regularity of Logarithmic Harary Graphs, (To appear) *Theoretical Computer Sciences*, 2009.
- [22] Baldoni R., Corsaro A., Querzoni L., Scipioni S., Tucci Piergiovanni S. Coupling-Based Internal Clock Synchronization for Large Scale Dynamic Distributed Systems, Technical report - MIDLAB 12/08 - Sapienza, Università di Roma, 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*, 2009
- [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. Harnessing the power of DHTs to build dynamic quorums in large-scale enterprise infrastructures, (to appear) In *Proceedings of the 2nd International Workshop on Large Scale Distributed Systems (LADIS)*, 2009.

- [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, 2009.
- [27] Baldoni R., Tucci Piergiovanni S. Eventual Leader Election in the Infinite Arrival Message-Passing System Model, MIDLAB Technical Report 10-2008, 2008.
- [28] Beraldi R., Querzoni L., Baldoni R. Low hitting time random walks in wireless networks, (to appear) Wireless Communications and Mobile Computing, 2009.
- [29] Busnel Y., Querzoni L., Baldoni R., Bertier M., Kermarrec A. On the deterministic tracking of moving objects with a binary sensor network, (submitted to an international journal), 2008.
- [30] Mian A. N., Baldoni R., Beraldi R. A Survey of Service Discovery Protocols in Multihop Mobile Ad Hoc Networks (to appear) *IEEE Pervasive Computing*, vol. 8, no. 1, pp. 66-74, 2009

### Patents

- [31] Ruffino S., Pazzini I., Marchisio M., Baldoni R., Milani A., Querzoni L. Method for persistent storage and robust retrieval of data in unstructured peer-to-peer networks EU patent, Telecom Italia, 2008

### 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 (Instituto 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 project: MURST FIRB "In.Sy.Eme - Integrated System for Emergency".

#### *Group members*

*Faculty members:* Francesco QUAGLIA, Bruno CICIANI.

*PostDoc:* Paolo ROMANO, Andrea SANTORO.

*PhD Students:* Pierangelo DI SANZO, Roberto PALMIERI.

**Dependable transactional 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. In this context, we have proposed innovative e-Transaction (exactly-once-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 reliability 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.

**Distributed mutual exclusion** The distributed mutual exclusion problem (DME) consists in defining a distributed coordination algorithm aimed at resolving conflicts resulting from several concurrent processes accessing a single, indivisible resource, that can only support one user at a time. The user accessing the resource is said to be in its critical section (CS), and the (safety) property guaranteeing the existence of at most one process in its CS at any time is known as mutual exclusion. In this context, we have defined the Weak Mutual Exclusion (WME) problem. Analogously to classical Distributed Mutual Exclusion (DME), WME serializes the accesses to a shared resource by exposing a simple lock interface. Differently from DME, however, the WME abstraction regulates the access to a replicated shared resource, whose copies are locally maintained by every participating process. We proved that, unlike DME, WME is solvable in a partially synchronous model, i.e. a system where the bounds on communication latency and on relative process speeds are not known in advance, or are known but only hold after an unknown time.

**Dependable data acquisition systems** Recent advances in wireless sensor networks and RFID technology have made sensor driven data acquisition services enter the realms of mainstream applications in a variety of diverse mission critical domains, such as public security, environmental protection, access control and supply chain management. In this context we have proposed a novel active replication protocol called APART (A Posteriori Active ReplicaTion). Unlike existing active replication solutions, APART does not rely on a-priori coordination schemes determining a same schedule of events across all the replicas, but it ensures replicas consistency by means of an a-posteriori reconciliation phase. The latter is triggered only in case the replicated servers externalize their state by producing an output event towards a different tier. On one hand, this allows coping with non-deterministic replicas. On the other hand, it allows attaining striking performance gains in the case of silent replicated servers, which only sporadically, yet unpredictably, produce output events in response to the receipt of a (possibly large) volume of input messages (as typical for sinks in data acquisition systems).

**High performance and QoS oriented (web-based) distributed systems** Edge computing is a powerful tool to face the challenging performance requirements proper of modern Internet applications. By replicating applications data and logic across a large number of geographically distributed servers, edge computing platforms allow a sensible increase in the proximity between clients and contents, as well as the enhancement of system scalability. However, in contexts where end-users can trigger transactional manipulations of the application state (e.g., e-Commerce, auctions or financial applications), the corresponding update requests typically need to be re-directed to the origin transactional data sources, thus nullifying any performance benefit arising from

data replication and related client proximity. To cope with this issue, we have presented a self-optimizing parallel invocation protocol, which exploits the path-diversity along the end-to-end interaction towards the origin sites by concurrently routing transactional requests towards multiple edge servers. Request processing is finally carried out by a single edge server, that is adaptively selected, with per-request granularity, as the most responsive one depending on current system conditions.

**Parallel and distributed simulation methodologies** One approach for high performance simulation consists of exploiting parallel techniques, where the simulation model is partitioned into objects (or Logical Processes), concurrently executing events on different CPUs and/or multiple CPU-Cores. For this type of simulation systems, a further run-time improvement arose from the exploitation of event uncertainty, both in time and space, which has led to more flexible synchronization protocols. Although this approach can provide significant performance gains, one drawback is the risk of less reliable simulation results due to potential bias induced by the mechanisms for resolving the uncertainty, which are sometimes exclusively targeted to run-time effectiveness. In this context we have focused on space uncertain simulation events in optimistic parallel simulation and introduce a mechanism that, compared to previous approaches, allows trading-off execution speed vs reliability of simulation results. In other words, our target is the achievement of high performance while controlling, at the same time, the bias introduced by space uncertainty on the simulation output.

**Consistent global snapshots in optimistic 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. This has been done by introducing a lightweight 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. Our proposal can support, in a performance effective manner, termination detection schemes based on global predicates. Another application concerns interactive simulation environments, where (aggregate) outputs about committed and consistent snapshots need to be frequently provided.

**Log/restore techniques for optimistic simulation objects** 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. 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.

**Synchronization techniques for 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).

**Publish/subscribe supports for federated simulation systems** In the HLA standard, message diffusion across the federation of simulators rely on publish/subscribe techniques. To achieve efficient publish/subscribe implementations one approach 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 services.

**Networked systems modeling** 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 superposition of different *M/M/1* queues. Since it is an approximation, we derive a methodology to decide in what instances the approximation is useful.

**Transactional systems modeling and optimization** 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 PostgreSQL), 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] 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.

**Conference proceedings**

- [2] Di Sanzo P., Ciciani B., Quaglia F. and Romano P., A Performance Model of Multiversion Concurrency Control, *Proc. 16th IEEE International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS)*, Baltimore, Maryland, USA, IEEE Computer Society Press, September 2008.
- [3] Gheri V., Castellari G. and Quaglia F., Controlling Bias in Optimistic Simulations with Space Uncertain Events, *Proc. 12th IEEE/ACM International Symposium on Distributed Simulation and Real Time Applications (DS-RT)*, IEEE Computer Society Press, Vancouver, British Columbia, Canada, October 2008.
- [4] Romano P., Carvalho N. and Rodrigues L., Towards Distributed Software Transactional Memory Systems , *Proc. 2th ACM Workshop on Large Scale Distributed Systems and Middleware (LADIS)*, York Town, New York, USA, ACM Press, September 2008.
- [5] 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.
- [6] 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 IEEE International Parallel and Distributed Processing Symposium - DPDNS Workshop (IPDPS)*, Miami, USA, IEEE Computer Society Press, April 2008.
- [7] 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.
- [8] 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. Winner of the Best Paper Award.
- [9] 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.

**Submitted papers, technical reports and others**

- [10] Quaglia F., On the Construction of Committed Consistent Global States in Optimistic Simulation, *International Journal of Simulation and Process Modelling*, to appear.
- [11] Romano P., Ciciani B., Santoro A. and Quaglia F., Accuracy vs Efficiency of Hyper-exponential Approximations of the Response Time Distribution of MMPP/M/1 Queues, *International Journal of Parallel, Emergent and Distributed Systems*, 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*, to appear.
- [13] Romano P. and Quaglia F., Parallel Invocation Schemes for QoS-oriented Multi-tier Transactional Applications, *IEEE Transactions on Computers*, pending revision.

- [14] Romano P., Quaglia F. and Ciciani B., APART+: Boosting APART Performance via Optimistic Pipelining of Output Events, *Proc. 14th IEEE Workshop on Dependable Parallel, Distributed and Network-Centric Systems (DPDNS)*, Rome, Italy, IEEE Computer Society Press, May 2009, to appear.
- [15] Romano P. and Rodrigues L., An Efficient Weak Mutual Exclusion Algorithm, submitted to the 8th IEEE International Symposium on Parallel and Distributed Computing, (ISPDC09).
- [16] Romano P., Rodrigues L. and Carvalho N., The Weak Mutual Exclusion Problem, *Proc. 23rd IEEE International Parallel and Distributed Processing Symposium*, Rome, Italy, IEEE Computer Society Press, May 2009, to appear.
- [17] Santoro A. and Quaglia F., Transparent Optimistic Synchronization in the High-Level-Architecture via Time Management Conversion, in preparation for submission to an international journal.

### 3.1.8 Programming Languages and Methodologies

Our group hosts the research activities of a number of scientists, coming from other departments of Sapienza 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, most recent EU research initiatives in which we participated are *mENU, Model for a European Networked University for e-learning* (e-learning Project, n.2002-0510/001-001-EDU-ELEARN, 2003/2004), and *QUIS, Quality, Interoperability and Standards in e-learning*, (Agreement n. 2004 – 3538 /001 – 001 ELE-ELEB14, 2005/2007);
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.

*Faculty members* Marco TEMPERINI.

**Open and Distance Learning** In collaboration with M. De Marsico and A. Sterbini (DI - Sapienza), and C. Limongelli (DIA - Un. 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 curricula, which are presently expressible only through informal (verbal) learning objectives. We devised different implementations, basing on logic programming and automated planning ([1, 2, 3]) and comprising an adaptation mechanism to the learning styles of the learner for the dynamic selection and presentation of learning material. The most firm advancements in the general framework for course configuration and adaptation have been presented in a paper accepted for publication ([5]) and in another submitted after invitation ([6]). We extended the latter applications by issues related to standards for e-learning (SCORM). 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 ([4]).

**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 has been conducted, in 2008, on planning and prototype implementations during the 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 A. Budoni (DAU - Sapienza), L. De Bonis (Dip. SAVA, Università del Molise) and A. Sterbini (DI - Sapienza), 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. The activity on this subject has been conducted, in 2008, on planning and prototype implementations during the development of *Laurea* thesis, in particular with the aim to extend the framework to comprise elements of collaborative learning models.

### Conference Proceedings

- [1] Limongelli C, Sciarrone F, Temperini M, Vaste G. Lecomps5: a Framework for the Automatic Building of Personalized Learning Sequences. In: M.D.Lytras J.M.Carroll, E.Damiani R.D.Tennyson (Eds.), *Emerging Technologies and Information Systems for the Knowledge Society - Proc. WSKS 2008*, LNAI 5288. Athens (Greece), Sept. 24-26 2008, Berlin, Heidelberg: Springer
- [2] Limongelli C, Sciarrone F, Temperini M, Vaste G. Lecomps5: a Web-Based Learning System for Course Personalization and Adaptation. In: M.B.Nunes and M.McPherson (Eds.) *Proc. e-Learning 2008*. Amsterdam (The Netherlands), Jul. 22-25, p. 325-333
- [3] Limongelli C, Sciarrone F, Temperini M, Vaste G. Personalized Learning and Personalized Tours: Two Sides of the Same Coin. In: *Proc. AI\*IA-IABC*, Cagliari (Italia), Sept. 11-13 2008
- [4] Sterbini A, Temperini M. Learning from peers: motivating students through reputation systems. In: *Proc. SPeL 2008*. Turku (Finland), Jul. 28 - Aug. 1 2008

### Submitted papers, technical reports and others

- [5] Limongelli C, Sciarrone F, Temperini M, Vaste G. The Lecomps5 Framework for Personalized Web-Based Learning: a Teacher's Satisfaction Perspective. *Computers in Human Behaviour*, Elsevier. 2009. accepted
- [6] Limongelli C, Sciarrone F, Temperini M, Vaste G. Adaptive Learning with the LS-Plan System: a Field Evaluation. submitted *IEEE Transactions on Learning Technologies*

## 3.2 System 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 and cognitive tasks in physiological and pathological conditions.

The group collaborates with 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* Simone ASNAGHI, Eugenio MATTEI.

**Analysis and modelling of metabolic systems** i) Data of multiple-meal experiments were analyzed by a mathematical model, previously developed, describing the dual control of insulin release by glucose and FFA [9, 10]. Parameters of  $\beta$ -cell secretion were estimated in control subjects as compared to obese patients before and after bariatric surgery. The results of this study evidenced that, after the surgery,  $\beta$ -cell sensitivity to glucose and NEFA was doubled while the 24-h insulin secretion decreased; the  $\beta$ -oxidation rate of  $\beta$ -cells was completely normalized and diabetes reverted. To deeply investigate on the mechanisms underlying the above described observations peripheral insulin sensitivity and  $\beta$ -cell function after either intravenous (IVGTT) or oral glucose (OGTT) tests and minimal model analysis were assessed in obese diabetic subjects before and after bilio-pancreatic diversion (BPD) as compared with normal-weight controls. The analysis of the experimental data by well assessed mathematical models (IVGTT and OGTT Minimal Models) suggests that the insulin resistance in type 2 diabetics could be related to some intestinal factor/s the effect of which was reduced by bariatric surgery [21].

**Estimation of the cortical activity and of the effective and functional cortical connectivity in humans** In the last year the aim of the work was devoted to characterize quantitatively the performance of some time-varying multivariate methods 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 [1, 16, 14]. In the same context new computational tools able to estimate cortical activity and connectivity from high-resolution EEG and fMRI recordings in humans were implemented [7, 19, 20]. The developed methods were used to detect mental states related to motor [6, 8, 13] or cognitive tasks [5, 2, 17] in healthy subjects by using realistic head models. This approach was also applied, in a group of disabled patients in order to study the possible modifications in the patterns of the cortical connectivity with respect to controls [18].

**Analysis of the brain potential modifications in patients affected by the Alzheimer disease (AD)** With reference to the analysis on the Alzheimer disease (AD), in the last year the computational tools, developed to analyze the connectivity of different cortical areas, were applied to evidence the possible changes in the parieto-to-frontal EEG synchronization in AD subjects [3]. The same methods were applied to study the relationships between the vascular lesions and the parietal-to-frontal coupling of EEG rhythms in subjects with a mild cognitive impairment (MCI, a pre-Alzheimer stage). These results are interpreted as supporting the additive

model according to which MCI state would result from the combination of cerebrovascular and neurodegenerative lesions [4].

### Journals

- [1] 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 Transactions on Biomedical Engineering*, vol. 55, pp.902-913, 2008.
- [2] Astolfi L, De Vico Fallani F, Cincotti F, Mattia D, Bianchi L, Marciani MG, Salinari S, Colosimo A, Tocci A, Soranzo R, Babiloni F Neural basis for brain responses to TV commercials: a high-resolution EEG study. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 16, pp. 522-531, 2008.
- [3] 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 PM Directionality of EEG synchronization in Alzheimer's disease subjects. *Neurobiology of Aging*, vol. 30, pp. 93-102, 2009.
- [4] 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*, vol. 29, pp.1355-1367, 2008.
- [5] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Marciani MG, Gao S, Salinari S, Soranzo R, Colosimo A, Babiloni F Structure of the cortical networks during successful memory encoding in TV commercials. *Clinical Neurophysiology*, vol. 119, pp. 2231-2237, 2008.
- [6] 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*, vol. 6, pp. 23-24, 2008.
- [7] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Tocci A, Salinari S, Marciani MG, Witte H, Colosimo A, Babiloni F Brain network analysis from high-resolution EEG recordings by the application of theoretical graph indexes. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 16, pp. 442-452, 2008.
- [8] De Vico Fallani F, Latora V, Astolfi L, Cincotti F, Mattia D, Marciani MG, Salinari S, Colosimo A, Babiloni F Persistent patterns of interconnection in time-varying cortical networks estimated from high-resolution EEG recordings in humans during a simple motor act. *Journal Of Physics. A, Mathematical and Theoretical*, vol. 41, article number 224014, 2008.
- [9] Salinari S, Bertuzzi A, Iaconelli A, Manco M, Mingrone G Twenty-four hour insulin secretion and beta cell NEFA oxidation in type 2 diabetic, morbidly obese patients before and after bariatric surgery. *Diabetologia*, vol. 51, pp. 1276-1284, 2008.
- [10] Salinari S, Bertuzzi A, Iaconelli A, Manco M, Mingrone G Enhancement of the incretin pathway in response to bariatric surgery is important for restoration of beta cell function. Reply to Komatsu M, Aizawa T [letter] *Diabetologia*, vol. 52, pp. 376-377, 2008.

### Articles in books

- [11] De Lazzari C, Salinari S Modelli di Sistemi Biologici Ed. Consiglio Nazionale delle Ricerche, 2009.

- [12] Salinari S. Ingegneria Biomedica. *Enciclopedia della scienza e della tecnica*. Istituto dell'Enciclopedia Italiana (Treccani), 2008.

### Conference proceedings

- [13] Astolfi L, Cincotti F, Mattia D, De Vico Fallani F, Colosimo A, Salinari S, Marciani MG, Witte H, Babiloni F Study of the time-varying cortical connectivity during the attempt of a foot movement by Spinal Cord Injured patients. *Conf Proc IEEE Eng Med Biol Soc. 2008 Aug. 2008* Page(s): 4551-4554
- [14] Astolfi L, Cincotti F, Mattia D, De Vico Fallani F, Salinari S, Marciani MG, Colosimo A, Witte H, Babiloni F Study of the time varying cortical connectivity from high-resolution EEG recordings. *Primo Congresso Nazionale di Bioingegneria July, 2008*
- [15] Astolfi L, Soranzo R, Cincotti F, Mattia D, Scarano G, Gaudiano I, Marciani MG, Salinari S, De Vico Fallani F, Babiloni F Assessing the memorization of TV commercials with the use of high resolution EEG: A pilot study. *Conf Proc IEEE Eng Med Biol Soc. 2008. Aug. 2008* Page(s): 3775-3758
- [16] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Salinari S, Marciani MG, Colosimo A, Babiloni F Connectivity evaluation from high-resolution EEG through the Brain Network Analysis *Primo Congresso Nazionale di Bioingegneria July, 2008*
- [17] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, Soranzo R, Salinari S, Marciani MG, Colosimo A, Babiloni F Cortical network topology during successful memory encoding in a lifelike experiment. *Conf Proc IEEE Eng Med Biol Soc. 2008. Aug. 2008* Page(s): 4007-4010
- [18] De Vico Fallani F, Sinatra R, Astolfi L, Mattia D, Cincotti F, Latora V, Salinari S, Marciani MG, Colosimo A, Babiloni F Community structure of cortical networks in spinal cord injured patients. *Conf Proc IEEE Eng Med Biol Soc. 2008. Aug. 2008* Page(s): 3995-3999

### Submitted papers, technical reports and others

- [19] Astolfi L, De Vico Fallani F, Cincotti F, Mattia D, Marciani MG, Salinari S, Sweeney J, Miller GA, He B, Babiloni F. Estimation of effective and functional cortical connectivity from neuro-electric and hemodynamic recordings. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* Accepted.
- [20] De Vico Fallani F, Astolfi L, Cincotti F, Mattia D, La Rocca D, Maksuti E, Salinari S, Marciani MG, Babiloni F, BVegso B, Kozmann G, Nagy Z. Application of theoretical graph methods for the analysis of functional networks from scalp EEG signals. *Anatomical Record* Submitted.
- [21] Salinari S, Bertuzzi A, Asnaghi S, Guidone C, Manco M, Mingrone G First-Phase Insulin Secretion Restoration And Differential Response To Glucose Load Depending On The Route Of Administration In Type 2 Diabetic Subjects After Bariatric Surgery. *Diabetes Care*, [Epub ahead of print], 2008.

### 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, Salvatore MONACO,

*Post Docs:* Gianluigi BALDESI, Andrea USAI.

*PhD Students:* Filippo FABBRI, Simone GABRIELE, Enrico GENTILI.

**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 the use in this context of the UML language [10].

**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. Starting from the geometric characterization of continuous time and discrete time dynamics obtained through the use of the chronological calculus formalism, controller and observer normal forms have been investigated in [17], [7], [22], [4]. The performed study emphasizes once more 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. In these works 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 geometric properties ensuring feedback linearization or observer design with linear error dynamics. Finally in [20], the equivalence under coordinates change and output transformation to observer canonical forms is analyzed for discrete time systems.

**Digital and switching control** Digital control methods, from emulation of continuous controllers to sample data design, require the knowledge of the discrete time model of the plant; an overview on this problem is given in [18], [21] controllers are discussed on the basis of nilpotency properties. In [19] a new passivity concept has been introduced starting from the sampled system properties, while in [16] the input state matching problem under multirate sampling has been addressed. Modelling, simulation and validation of different control strategies in the aerospace domain have been analysed in [9].

**Sensors, sensor networks 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, 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, measurement estimations algorithms and coordinated constrained control. For the first aspect, in [8] a visual system as a position sensor in a mobile robotic platforms control problem has been presented and validated. The second aspect has been addressed in [3] and [13], where the problem of a measurement noise reduction has been faced making use of some advantages introduced by mobile sensors. The problem of area coverage, with centralized ([6]) and distributed ([14]) approaches, has been faced and suboptimal solutions have been proposed under different types of constraints. Some of such constraints have been addressed specifically: in [1] the problem of preserving the possibility of communications between any couple of sensor nodes during the motion has been referred; an equivalent but more general problem, the connectivity maintenance, is faced in [15]. One of the advantages in the use of mobile sensor networks has been highlighted in [2] and [12], where the problem of robustness with respect to sensor faults has been approached.

### Journals

- [1] Gabriele S. and Di Giamberardino P., Mobile sensors networks under communication constraints. *WSEAS Transactions on Systems*, 7(3):165–174, 2008.
- [2] Gabriele S. and Di Giamberardino P., A unified approach for heterogeneity and node fault robustness in dynamic sensor networks. *WSEAS Transactions on Communications*, 7(7):685–694, 2008.
- [3] Gabriele S. and Di Giamberardino P., Redundant coverage for noise reduction in dynamic sensor networks. *WSEAS Transactions on Systems*, 7 (10):855–865, 2008.

### Articles in books

- [4] Battilotti S. and 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.
- [5] Di Giamberardino P. and Belfiore N. P., Analisi dinamica di sistemi multibody mediante ambienti di modellazione e simulazione a blocchi. In *Cinematica e dinamica dei sistemi multibody, vol.II*, F. Cheli e E. Pennestrì Eds., pp. 235–262, Ambrosiana, MILANO – ITA, 2008.
- [6] Gabriele S. and Di Giamberardino P., The Area Coverage Problem for Dynamic Sensor Networks. In *New Developments in Robotics, Automation and Control*, A. Lazinica Ed., pp. 1–26, In-Tech, HRV, 2008.
- [7] Monaco S. and 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.
- [8] Usai A. and Di Giamberardino P., Homography-based Control of Nonholonomic Mobile Robots: a Digital Approach. In *Frontiers in Robotics, Automation and Control*, A. Zemliak Ed., pp. 327–340, In-Tech, HRV, 2008.

**Conference proceedings**

- [9] 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*, August 2008.
- [10] De Carli A., Andreozzi S. and Fiaschetti A., Requirement documentation of a controlled complex motion system In *Proc. 10th IEEE Workshop on Advanced Motion Control*, 2008.
- [11] Fabbri F., Lassailly Y., Peretti J., Boilot J.-P., Lahlil K. and Tard C., Contrôle Optique du Mouvement et de l'Organisation de Nanoparticules. Presented at *C'NANO IdF*, Ile De France, February 2008.
- [12] Gabriele S. and Di Giamberardino P., Node fault robustness for heterogeneous dynamic sensor networks, in *Proceedings 7th WSEAS International Conference on Instrumentation, Measurement, Circuits and Systems*, pp. 163–168, Hangzhou, China, April 2008.
- [13] Gabriele S. and Di Giamberardino P., Measurement noise reduction in dynamic sensor networks. in *Proceedings 12th WSEAS International Conference on Systems*, Heraklion, Crete, Greece, pp. 250–255, July 2008.
- [14] Gabriele S. and Di Giamberardino P., Mobile sensors networks: a distributed solution to the area coverage problem. in *Proceedings 16th Mediterranean Conference on Control and Automation*, Ajaccio, Corsica, France, pp. 1844–1849, July 2008.
- [15] Gabriele S. and Di Giamberardino P., A distributed approach to connectivity maintenance in dynamic sensor networks. in *Proc. IASTED International Conference on Sensor Networks*, Crete, Greece, September-October 2008.
- [16] Monaco S. and Normand-Cyrot D., On input-state matching under multirate digital control. In *Proc. SICPRO'08*. Mosca, January 2008.
- [17] Monaco S. and Normand-Cyrot D., Digital controllers for nilpotent Lie Algebra of order 3. In *Proc. SICPRO'08*. Mosca, January 2008.
- [18] Monaco S. and Normand-Cyrot D., Méthodologies d'analyse et de synthèse pour les systèmes non linéaires échantillonnés. *Plenary, Proc. CIFA'08*, Bucarest, August 2008.
- [19] Monaco S., Normand-Cyrot D. and Tiefensee F., From passivity under sampling to a new discrete-time passivity concept. *Proceed. 46-th IEEE-CDC*, Cancun, Messico, December 2008.

**Submitted papers, technical reports and others**

- [20] Califano C., Monaco S. and Normand-Cyrot D., Observers with linear error dynamics for discrete time multi output systems. *Submitted to Automatica*, 2007.
- [21] Monaco S. and Normand-Cyrot D. and Di Giamberardino P. Piecewise constant control of dynamics evolving on Lie Groups: a simple case study. *Proceedings SICPRO'09*, Mosca, Russia, January 2009,
- [22] Monaco S. and Normand-Cyrot D. Linearization by output-injection under approximate sampling. *European Journal of Control*, Special issue 2009, to appear.

### 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 problem of non rigid motion estimation from a sequence of blurred and noisy images have been considered. Also the problems of statistical analysis of human retina pseudoimages and of modelling tumour spheroids have been studied.

In the second area the application of filtering and optimization techniques to traffic control in a wireless communication network was considered (part of this latter research was developed in the framework of the APICE and WEIRD scientific projects).

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**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 therefore suitable approximate filtering techniques are requested. In particular gaussian approximations by linearization methods have been considered. In order to reduce the computing complexity a relevant 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 developed 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.

Multicellulars tumour spheroids (MTS) are *in vitro* tumour models, the complexity of which is intermediate between that of conventional monolayer culture and *in vivo* models. MTS are essentially growing aggregates of tumour cells in suspension culture. A mathematical model for the radiation response of MTS has been formulated in order to follow the available experimental data and to predict some typical behaviors.

**Modeling, filtering and optimal control of communication networks** The problem of Congestion and Admission Control for a telecommunication network has been considered. 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 synthesizability:* 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.

A second problem which has been tackled in the area of communication networks concerns the optimal routing, that is the determination of the control actions which, at each time, optimizes the overall traffic distribution over the network paths.

## Journals

- [1] 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, 2008.
- [2] Bruni C., Ferrone C., Koch G., Lucchetti M., Motion Identification from Image Sequences: Information Theory and Pixel Selection, *Computer and Mathematics with Applications*, **56**, 375-386, 2008.

## Books

- [3] Bruni C., Ferrone C., *Metodi di Stima per il Filtraggio e l'Identificazione dei Sistemi*, Ed. Aracne, 2008.

## Conference proceedings

- [4] Bertuzzi A., Bruni C., Fasano A., Gandolfi A., Papa F., Sinisgalli C., A Mathematical Model for the Radiation Response of Tumour Spheroids, *SIMAI 2008 Conference*, Rome, September 2008.
- [5] Bruni C., De Juan J., Ferrone C., Giannini D., Grzywacz N.M., Huang D., Koch G., Russo V., Tan O., Analysis of Retinal Tomographic Pseudoimages for Diagnostic Purpose, *Mini Euro Conference on Computational Biology, Bioinformatics and Medicine*, Rome, September 2008.

## Submitted papers, technical reports and others

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

The book “Analysis and Design of Nonlinear Control Systems”, A. Astolfi and L. Marconi (Eds) Springer Verlag, has been published to celebrate the prolific and high-impact career of Prof. Alberto Isidori on the occasion of his 65th birthday. The book was followed by the workshop in his honour “Analysis and Design of Nonlinear Control Systems: a 4-day Control Event”, held on May 13–16, 2008 at the Imperial College and at the Royal Society, London, UK.

Francesco Delli Priscoli is the scientific responsible of several research projects financed by the UE and by the MIUR, 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 2008, work contracts have been granted on these activities to 17 young engineers and about 40 PhD and Master theses have been discussed on these issues.

Claudio De Persis leads the workpackage *Distributed event-based networked nonlinear control of Plug & Play Process Control*, a five-year Research Program supported by The Danish Research Council for Technology and Production Sciences.

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**Control under communication constraints** A possible approaches to control systems with a communication channel in the feedback loop is to assume that the transmission of the feedback packets occur at given times. In [5], we introduce a new class of dynamic encoders for continuous-time nonlinear control systems which update their parameters only at discrete times. A sampled-data encoded-feedback control law is designed to guarantee semi-global practical stability. For the class of nonlinear systems in feedforward form, we design in [13] 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.

**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 [1]. 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.

In [18] (a detailed version will appear in [30]) we present a novel observer design for a class of single-output nonlinear systems with Markov jumps and resets. The estimation process is reset at these random times, depending on the reset values of the state process, and then evolves as a deterministic estimate of the state process itself. We prove that, as long as the mathematical expectation of the dwell times has a positive lower bound and the transition rate of the jump process at the first exit time out of any point is bounded, the state estimation error of the switching dynamics asymptotically converges to zero with probability one.

**Network control and handling** This research has been mainly performed in the framework of several EU and MIUR projects. 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.

*Power System Control and Planning* We designed, simulated and tested EMS/SCADA architectures for management and control of power systems with distributed and renewable generation. We developed an optimisation approach to find optimal generation portfolio by using Genetic Algorithms, Monte Carlo Estimators and Risk Aversion factorisation for Net Present Value target functions.

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 ( [7], [10], [11], [12], [14], [15], [19], [23], [24], [28], [29], [31], [32], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46] ), as well as in a plenty of project deliverables.

**Nonlinear control applications** In [9] a novel feedback controller for cranes employed in heavy-lift offshore marine operations is presented. Experimental validations show improvements with respect to a previous feedforward controller.

**Nonlinear regulation** Research in this area has been addressed to various problems of nonlinear output regulation. In paper [8] 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 [6] 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 goal of paper [9] 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 contribution of papers [20] and [34] consists in showing that, when the controlled output is unmeasurable, a design based on certainty equivalence is effective for determining a controller that achieves semiglobal output regulation. In [33] the latter design is successfully applied to a nonlinear benchmark system.

**Quantized control** By quantized control it is meant a piece-wise constant control law which takes value in a *finite* set. In [21], motivated by the case study in [22], results on the problem of stabilizing a nonlinear continuous-time system by quantized control are presented. The basic tool is a discontinuous version of the so-called semi-global backstepping lemma. We are pursuing experimental validation of our theoretical findings on a number of industrial case studies which include an advanced climate control unit [4], and a large-scale district heating system [22].

**Stabilization of nonlinear systems** In [2] 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. A design tool for the design of composite filtered Lyapunov functions is given, and examples show improvements over existing literature. In [17] the stabilization problem of interconnected systems is tackled by using filtered Lyapunov functions and advantages over existing methods are illustrated through examples.

Paper [25] investigates a few issues related to the problem of robust output feedback stabilization of nonlinear non-minimum phase systems.

In papers [26] and [27] we present a general tool to handle the presence of zero dynamics which are asymptotically, but not locally exponentially, stable in problems of robust nonlinear stabilization by output feedback.

## Journals

- [1] Battilotti S., Control over a communication channel with random noise and delays, *Automatica*, 44, 348-360, 2008.
- [2] Battilotti S., Filtered Lyapunov Functions and their Applications in the Stability Analysis of Nonlinear Systems, *IEEE Transactions on Automatic Control*, 53, 434-439, 2008.
- [3] Celani F., Isidori A., Marconi L. A reduction paradigm for output regulation, *International Journal of Robust and Nonlinear Control*, 18(7), 756-781, 2008.
- [4] De Persis C., Jessen J.J., Izadi-Zamanabadi R., Schiøler H. A distributed algorithm for internal flow management in a multi-zone climate control unit. *International Journal of Control*, 81(1), 89-106, 2008.
- [5] De Persis C. and Nešić D. Practical encoders for controlling nonlinear systems under communication constraints. *Systems & Control Letters*, 57, 8, 654-662, 2008.
- [6] Delli Priscoli F., Isidori A., Marconi L. Output regulation with redundant measurements, *SICE Journal of Control, Measurement and Systems Integration*, 1, 92-101, 2008.
- [7] Delli Priscoli F., Pompili D., A Closed-loop Fuzzy Traffic Controller for Fair Bandwidth Sharing, *ACM SigBed Review*, 5, 2008.
- [8] Isidori A., Byrnes C.I. Steady-state behaviors in nonlinear systems with an application to robust disturbance rejection, *Annual Reviews in Control*, 32, 1-16, 2008.

- [9] Messineo S., Celani F., Egeland O. Crane feedback control in offshore moonpool operations. *Control Engineering Practice*, 16(3), 356-364, 2008.
- [10] Pietrabissa A., A Multi-Model Reference Control Approach for Bandwidth-on-Demand in Satellite Networks, *Control Engineering Practice*, 16(7), 847-860, 2008.
- [11] Pietrabissa A., An Alternative LP Formulation of the Admission Control Problem in Multi-Class Networks, *IEEE Transaction on Automatic Control*, 53(3), 839-845, 2008.
- [12] Pietrabissa A., Admission Control in UMTS Networks based on Approximate Dynamic Programming, *European Journal of Control*, 14(1), 62-75, 2008.

### Articles in books

- [13] 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.
- [14] Delli Priscoli F., Pietrabissa A., Paving the Way Towards the Control of Wireless Telecommunication Networks. In *Analysis and Design of Nonlinear Control Systems. In Honor of Alberto Isidori*. A. Astolfi, L. Marconi eds., Springer Verlag, 319-338, 2008.
- [15] Pietrabissa A., Baudin C., Radio Resource Management for next generation DVB-RCS systems. In *IP Networking over Next-Generation Satellite Systems*. L. Fan, H. Cruickshank eds., Springer New York, 91-101, 2008.
- [16] Baudoin C., Fan L., Callejo E., Pietrabissa A., Rodriguez F., Ramos A., Fairhurst G., Arnal F., Santoro G., New Architecture for Next Generation Broadband Satellite Systems: the SATSIX Approach. In *IP Networking over Next-Generation Satellite Systems*. L. Fan, H. Cruickshank eds., Springer New York, 1-13, 2008.

### Conference proceedings

- [17] Battilotti S., Constructive Lyapunov design of dynamic state feedback controllers, *Proceedings of the 47th IEEE Conference on Decision and Control*, Cancun, Mexico, 3782-3786, 2008.
- [18] Battilotti S., State estimation of nonlinear systems with Markov state reset, *Proceedings of the 47th IEEE Conference on Decision and Control*, Cancun, Mexico, 298-302, 2008.
- [19] Castrucci M., Delli Priscoli F., Buccella C., Puccio V., Marchetti I., Connection Admission Control in Wi-Max Networks, in *Proceedings of the ICT Mobile Summit 2008*, Stockholm, Sweden, June, 2008.
- [20] Celani F. Certainty equivalence in nonlinear output regulation with unmeasurable regulated error, in *Proceedings of the 17th IFAC World Congress*, Seoul, South Korea, July, 2008.
- [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., Kallestøe C.S. Proportional and proportional-integral controllers for a nonlinear hydraulic network. Invited paper in *Plug & Play Process Control*, J. Stoustrup (Organizer). In *Proc. 17th IFAC World Congress*, Seoul, Korea, July 6-11, 2008.
- [23] Delli Priscoli F., Suraci V., Castrucci M., Tamea G., Di Pilla G., De Vecchis W., Inter-MAC: Convergence at MAC Layer in Home Gigabit Networks, in *Proceedings of the ICT Mobile Summit 2008*, Stockholm, Sweden, June, 2008.

- [24] Delli Priscoli F., Suraci V., Di Giorgio A., Calabrese I., La Sala G., A Reinforcement Learning Admission Control for Wireless Next Generation Networks, in *Proceedings of the ICT Mobile Summit 2008*, Stockholm, Sweden, June, 2008.
- [25] Isidori A., Marconi L. A note on robust output feedback stabilization of nonlinear nonminimum phase systems, in *Proceedings of the 17th IFAC World Congress*, Seoul, South Korea, July, 2008.
- [26] Isidori A., Marconi L. Robust asymptotic stabilization of nonlinear systems with non-hyperbolic zero dynamics: Part I, in *Proceedings of the 47th IEEE Conference on Decision and Control*, Cancun, Mexico, 2008.
- [27] Isidori A., Marconi L. Robust asymptotic stabilization of nonlinear systems with non-hyperbolic zero dynamics: Part II, in *Proceedings of the 47th IEEE Conference on Decision and Control*, Cancun, Mexico, 2008.
- [28] Melhus I., Gayraud T., Nivor F., Gineste M., Arnal F., Pietrabissa A., Fan L., SATSIX Cross-layer Architecture, in *Proc. of 2008 International Workshop on Satellite and Space Communications (IWSSC'08)*, Toulouse, France, October, 203-207, 2008
- [29] Mercurio A., Di Giorgio A., Cioci P., Open Source Implementation of Monitoring and Controlling Services for EMS/SCADA Systems by means of Web Services. In *Proceedings of the Innovation for Sustainable Production Conference - i-SUP2008*. Bruges, Belgium, April 22-25, 2008.

#### Submitted papers, technical reports and others

- [30] Battilotti S., Observer design for nonlinear systems with Markov chain, to appear in *Journal of Robust and Nonlinear Control*, 2009.
- [31] Bruni C., Delli Priscoli F., Koch G., Marchetti I., Resource Management in Network Dynamics: an Optimal Approach to the Admission Control Problem, submitted to *Comp. Mathematics Appl.*, 2008.
- [32] Bruni C., Delli Priscoli F., Koch G., Marchetti I., The Connection Admission Problem in Internet Networks: an Optimal Procedure, submitted to the *European Control Conference (ECC)*, 2008.
- [33] Celani F., Certainty-equivalence design for output regulation of a nonlinear benchmark system, to appear in *Proceedings of the 2009 American Control Conference*, 2009.
- [34] Celani F., Certainty equivalence in nonlinear output regulation with unmeasurable output, submitted to *Systems & Control Letters*, 2008.
- [35] Conforto P., Delli Priscoli F., Game Theoretic Model and Distributed Admission Control for an Innovative Distributed QoS Routing", submitted to *European Journal of Control*, 2008.
- [36] Delli Priscoli F., A Control Based Solution for Integrated Dynamic Capacity Assignment, Congestion Control and Scheduling in Wireless Networks, submitted to *European Journal of Control*, 2008.
- [37] Delli Priscoli F., Control-based Resource Management in Wireless Networks, submitted to the *European Control Conference (ECC)*, 2008.
- [38] Delli Priscoli F., Isidori A., Marconi L., Performance Limitations in Tracking Problems for Non-minimum Phase Nonlinear Systems, accepted for publication in *System and Control Letters*, 2009.

- [39] Delli Priscoli F., Pietrabissa A., Control-based Connection Admission Control and Downlink Congestion Control Procedures for Satellite Networks, submitted to *The Journal of the Franklin Institute*, 2008.
- [40] Delli Priscoli F., Pompili D., A Demand Assignment Algorithm based on a Markov Modulated Chain Prediction Model for Satellite Bandwidth Allocation, to appear in *ACM-Kluwer Wireless Networks*, 2009.
- [41] Di Giorgio A., Mercurio A., Pimpinella L., A Novel Approach to Generation Portfolio Optimisation by using Genetic Algorithms and Stochastic Methods, submitted to the *10th European Control Conference*, Budapest, August 23-26, 2009.
- [42] Mercurio A., Di Giorgio A., Cioci P., Open Source Implementation of Monitoring and Controlling Services for EMS/SCADA Systems by means of Web Services, to appear in *IEEE Transactions on Power Delivery*, 2009.
- [43] Pietrabissa A., Delli Priscoli F., Admission Control in Variable Capacity Communication Networks, to appear in *Modelling, Estimation and Control of Networked Complex Systems*, Springer-Verlag, London, 2009.
- [44] Pietrabissa A., A new LP formulation of the admission control problem modelled as a MDP, submitted to *International Journal of System Science*, 2008.
- [45] Pietrabissa A., A policy approximation method for the UMTS connection admission control problem modeled as a MDP, to appear in the *International Journal of Control*, 2009.
- [46] Pietrabissa A., Optimal call admission and call dropping control in links with variable capacity, to appear in the *European Journal of Control*, 14(1), 2009.

### 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. The DIS Robotics Laboratory (<http://www.dis.uniroma1.it/labrob>) was established in 1987. Available facilities include two manipulators, two underactuated systems, two four-legged and seven wheeled mobile robots with various sensing equipments. Active grants include the EU FP-6 STREP projects *Cyber-Walk* and *PHRIENDS*, and the national PRIN 2007 *SICURA* project (with A. De Luca as national coordinator). In 2008, we have cooperated with the following foreign institutions: *DLR* (Germany), *TUM* (Germany), *MPI* (Germany), *ENSTA* (France) and *IRISA/INRIA* (France). In Italy, we have collaborations with *Fondazione Santa Lucia* in Roma, *Università di Bologna*, *Università di Cassino*, *Università di Napoli Federico II*, *Università di Roma Tre*, and *Università di Pisa*. In 2008, a member of this group (G. Oriolo) has co-authored a robotics textbook [7, 36]. Another member (P. Robuffo Giordano) received in 2008 the Claudio Maffezzoni Award for the best Italian PhD thesis in System Science completed in the previous year. Paper [17] (co-authored by A. De Luca) received the Best Application Paper Award at the IROS 2008 conference.

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**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* [6], the largest editorial effort in our field.

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 [19], 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 [20]. In particular, the static feedback linearization technique has been applied to a specific experimental device, the VSA-II developed in Pisa, in [23].

**Robots with flexible links** Lightweight manipulators with very slender mechanical design usually imply the presence of vibrations due to distributed link flexibility. Modeling and control techniques for robots with link flexibility are surveyed in the second part of a chapter of the Springer *Handbook of Robotics* [6]. 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 [13].

**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* [5].

Redundancy has been used in [14] 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.

A task-constrained motion planning method for redundant manipulators has been presented in [34]. Based on the principle of kinodynamic planning, the proposed planner allows to execute a given task with arbitrary precision while avoiding obstacles.

**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.

A distance function which takes into account the nonholonomic constraints and the non-symmetric nature of the Dubin's car (a mobile robot moving only forward) has been defined in [35] where an analytical method for its computation is also provided.

An approximate algorithm for motion planning of generic (i.e., not transformable in canonical forms) nonholonomic systems has been devised in [33].

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 in [9]. The method does not require specific motion trajectories and has been tested on a *Khepera III* robot with HOKUYO laser rangefinder.

**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 robust to calibration errors. In [12], a general approach for redundancy exploitation in IBVS tasks has been proposed and experimentally evaluated.

On-line estimation of the depth of visual point features, and integration of such information in IBVS schemes, is the subject of [3]. The same technique, which is based on nonlinear observation theory, has been extended to non-point features (image moments) in [21]. Also, depth estimation has been used as a component of a VS scheme for assembling complex planar parts in [22].

For wheeled nonholonomic mobile robots equipped with an on-board camera, we have 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 [10, 11].

Autonomous vehicle navigation based on a database of previously recorded images is considered in [24]. In particular, six different appearance-based (one position-based, five image-based) controllers are proposed and compared for a nonholonomic vehicle equipped with a monocular camera. Simulation and experimental results show that the two controllers based on the image jacobian, that exploit the epipolar geometry to estimate feature depth, outperform the others.

**Motion planning** Modeling robot motion planning with uncertainty in a Bayesian framework leads to a computationally intractable stochastic control problem. In [8], 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 Fisher 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 to maximize the utility of the motion. Building on this idea, we have proposed both decentralized exploration strategies for teams of mobile robots [15, 29] and methods for exploration with general robotic systems, such as fixed-base and mobile manipulators [16, 32].

A relevant problem for merging maps acquired by multi-robot teams is mutual localization. In [30, 31] we have considered in particular the situation where each robot is equipped with a sensory system that detects the relative position of other robots, but does not provide neither their identity nor their orientation. To solve the problem, an innovative algorithm is proposed that builds sets of possible relative pose hypotheses, whose output is processed by a data associator and a multiple EKF to select the best hypothesis. The performance of the developed localization system is assessed using both simulations and experiments.

**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 [4]. We have further developed our fast and reliable method for detection and reaction to unexpected collisions. In particular, a modified recursive Newton-Euler method has been introduced for the efficient numerical computation of the residual vector used for the detection [26]. Moreover, the residual-based collision detection technique was shown to work well also for variable stiffness actuation (VSA) devices, without the need of joint torque measurements [23]. 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 [17] (this paper was awarded as Best Application Paper at IROS'08). The safety of the approach has been evaluated also when the robot is equipped with sharp tools and hits on soft biological tissues [18].

**Locomotion platforms** 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 treadmill, 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 treadmill motion [37]. The control method has been then extended to the omnidirectional 2D platform *CyberWalk*, the largest locomotion device in the world intended for 'natural walking' in VR [27]. The *CyberCarpet* is another 2D small-scale locomotion device developed within our *CyberWalk* European project. It is a non-holonomic platform consisting of a turntable with a linear treadmill and a ball array carpet mounted on it. The mechanical design, the visual localization of the walker, and various nonlinear control laws for smoothly keeping the walking user around the center of the platform under perceptual constraints are presented in [28].

**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 [2] we present a project (funded by the Italian *Telethon Foundation*) 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 [1]. Single step, semi-autonomous, and autonomous operating modes have been realized to provide different levels of interaction with the *AIBO*. The performance of the navigation system has been tested in simulation as well as experiments. 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, and in particular humanoid soccer robot for the *RoboCup* competition. In [25], two learning methods are presented for humanoid walking gaits based on the Policy Gradient algorithm. It is shown that an extension of the classic Policy Gradient algorithm that takes into account parameter relevance yields improved solutions when only a few experiments are available.

## Journals

- [1] Cherubini A., Oriolo G., Macri F., Aloise F., Cincotti F., and Mattia D., Development of a multimode navigation system for an assistive robotics project. *Autonomous Robots*, 25:383–404, 2008.
- [2] 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. *Brain Research Bulletin*, 75:796–803, 2008.
- [3] De Luca A., Oriolo G., and Robuffo Giordano P., Feature depth observation for image-based visual servoing: Theory and experiments. *The International Journal of Robotics Research*, 27(10):1093–116, 2008.
- [4] 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.

### Articles in books

- [5] Chiaverini S., Oriolo G., and Walker I. D., Chapter 11: Kinematically redundant manipulators, in B. Siciliano, O. Khatib (Eds.) *Springer Handbook of Robotics*, pp. 245–268, Springer Verlag, Berlin, 2008.
- [6] De Luca A. and Book W., Chapter 13: Robots with flexible elements, in B. Siciliano, O. Khatib (Eds.) *Springer Handbook of Robotics*, pp. 287–319, Springer Verlag, Berlin, 2008.

### Books

- [7] Siciliano B., Sciavicco L., Villani L., and Oriolo G., *Robotica: Modellistica, Pianificazione e Controllo*. McGraw-Hill, Milano, 2008.

### Conference proceedings

- [8] Censi A., Calisi D., De Luca A., and Oriolo G., A Bayesian framework for optimal motion planning with uncertainty. *Proc. 2008 IEEE Int. Conf. on Robotics and Automation*, pp. 1798–1805, Pasadena, CA, USA, 2008.
- [9] Censi A., Marchionni L., and Oriolo G., Simultaneous maximum-likelihood calibration of robot and sensor parameters. *Proc. 2008 IEEE Int. Conf. on Robotics and Automation*, pp. 2098–2103, Pasadena, CA, USA, 2008.
- [10] Cherubini A., Chaumette F., and Oriolo G., A position-based visual servoing scheme for following paths with nonholonomic mobile robots. *Proc. 2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 1648–1654, Nice, F, 2008.
- [11] Cherubini A., Chaumette F., and Oriolo G., An image-based visual servoing scheme for following paths with nonholonomic mobile robots. *Proc. 10th Int. Conf. on Control, Automation, Robotics and Vision*, pp. 108–113, Hanoi, VN, 2008.
- [12] De Luca A., Ferri M., Oriolo G., and Robuffo Giordano P., Visual servoing with exploitation of redundancy: An experimental study. *Proc. 2008 IEEE Int. Conf. on Robotics and Automation*, pp. 3231–3237, Pasadena, CA, USA, 2008.
- [13] De Luca A. and Panzer H., Rest-to-rest motion of a one-link flexible arm with smooth bang-bang torque profile, *Proc. 9th Int. Conf. on Motion and Vibration Control*, München, D, 2008.
- [14] De Luca A. and Ferrajoli L., Exploiting robot redundancy in collision detection and reaction. *Proc. 2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 3299–3305, Nice, F, 2008.
- [15] Franchi A., Freda L., Marchionni L., Oriolo G., and Vendittelli M., Decentralized cooperative exploration: Implementation and experiments. *Proc. 10th Int. Conf. on Intelligent Autonomous Systems*, pp. 348–355, Baden-Baden, D, 2008.
- [16] Freda L., Oriolo G., and Vecchioli F., Sensor-based exploration for general robotic systems. *Proc. 2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 2157–2164, Nice, F, 2008.
- [17] Haddadin S., Albu-Schäffer A., De Luca A., and Hirzinger G., Collision detection and reaction: A contribution to safe physical human-robot interaction. *Proc. 2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 3356–3363, Nice, F, 2008.
- [18] 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. *Proc. 6th IARP/IEEE/EURON Work. on Technical Challenges for Dependable Robots in Human Environments*, Pasadena, CA, USA, 2008.

- [19] Le Tien L., Albu-Schäffer A., De Luca A., and Hirzinger G., Friction observer and compensation for control of robots with joint torque measurements. *Proc. 2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 3789–3795, Nice, F, 2008.
- [20] Palli G., Melchiorri C., and De Luca A., On the feedback linearization of robots with variable stiffness. *Proc. 2008 IEEE Int. Conf. on Intelligent Autonomous Systems*, pp. 1753–1759, Pasadena, CA, USA, 2008.
- [21] Robuffo Giordano P., De Luca A., and Oriolo G., 3D structure identification from image moments. *Proc. 2008 IEEE Int. Conf. on Robotics and Automation*, pp. 93–100, Pasadena, CA, USA, 2008.
- [22] Robuffo Giordano P., Stemmer A., Arbter K., and Albu-Schäffer A., Robotic assembly of complex planar parts: An experimental evaluation. *Proc. 2008 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 3775–3782, Nice, F, 2008.

### Submitted papers, technical reports and others

- [23] Bicchi A., De Luca A., Flacco F., and Schiavi R., Nonlinear decoupled motion-stiffness control and collision detection/reaction for the VSA-II variable stiffness device. Submitted for presentation at *2009 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, St. Louis, MO, USA, October 2009.
- [24] Cherubini A., Chaumette F., Colafrancesco M., Freda L., and Oriolo G., Comparing appearance-based controllers for nonholonomic navigation from a visual memory. Submitted for presentation at *2009 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, St. Louis, MO, USA, October 2009.
- [25] Cherubini A., Giannone F., Iocchi L., Lombardo M., and Oriolo G., Policy gradient method for a humanoid soccer robot. Accepted for publication in *Robotics and Autonomous Systems*, 2009.
- [26] De Luca A. and Ferrajoli L., A modified Newton-Euler method for dynamic computations in robot fault detection and control. Accepted for presentation at *2009 IEEE Int. Conf. on Robotics and Automation*, Kobe, J, May 2009.
- [27] De Luca A., Mattone R., and Robuffo Giordano P., Control design and experimental evaluation of the 2D *CyberWalk* platform. Submitted for presentation at *2009 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, St. Louis, MO, USA, October 2009.
- [28] De Luca A., Mattone R., Robuffo Giordano P., Ulbrich H., Schwaiger M., Van der Bergh M., Koller-Meier E., and Van Gool L., Motion control of the *CyberCarpet*. Submitted for publication in *IEEE Transactions on Control Systems Technology*, March 2009.
- [29] Franchi A., Freda L., Oriolo G., and Vendittelli M., The Sensor-based Random Graph method for cooperative robotic exploration. Accepted for publication in *IEEE/ASME Transactions on Mechatronics*, 2009.
- [30] Franchi A., Oriolo G., and Stegagno P., Mutual localization of a multi-robot team with anonymous relative position measures. Tech. Rep. no. 1/2009, Dipartimento di Informatica e Sistemistica, 2009.
- [31] Franchi A., Oriolo G., and Stegagno P., Mutual localization of a multi-robot team with anonymous relative position measures. Submitted for presentation at *2009 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, St. Louis, MO, USA, October 2009.

- [32] Freda L., Oriolo G., and Vecchioli F., An exploration method for general robotic systems equipped with multiple sensors. Submitted for presentation at *2009 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, St. Louis, MO, USA, October 2009.
- [33] Jean F., Long R., Oriolo G., and Vendittelli M., An approximate algorithm for nonholonomic motion planning. Tech. Rep. no. 651, Ecole Polytechnique, Centre de Mathématiques Appliquées, 2009.
- [34] Oriolo G., and Vendittelli M., A kinodynamic approach to task-constrained motion planning for redundant manipulators. Submitted for presentation at *2009 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, St. Louis, MO, USA, October 2009.
- [35] Robuffo Giordano P. and Vendittelli M., Time-optimal collision trajectories for the Dubins car. Accepted for publication in *IEEE Transactions on Robotics*, 2009.
- [36] Siciliano B., Sciavicco L., Villani L., and Oriolo G., *Robotics: Modelling, Planning and Control*. Springer, London, 2009.
- [37] 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. Accepted for publication in *ACM Transactions on Applied Perception*, 2009.

### 3.3 Management Science

#### 3.3.1 Combinatorial Optimization

The research activity of the Combinatorial Optimization group is mostly devoted to theoretical, methodological and computational aspects related to the following problems:

- telecommunication network design, planning and loading problems;
- job-shop scheduling problems;
- computational biology and polymer sequencing problems;
- data mining and universe selection problems;
- satisfiability;
- cardinality constrained optimization problems in supervised learning.

The group is currently cooperating with Maastrich University, Oslo University, Università di Roma Tor Vergata, Università dell'Aquila, Università di Lecce, Politecnico di Milano, Texas Tech University and Fondazione Ugo Bordoni. It is currently involved in several national and international research project, including the MIUR projects M3-CAST and APICE, both devoted to Wireless Network Planning.

#### *Group members*

*Faculty members* Carlo MANNINO, Antonio SASSANO.

*Post-docs* Silvia CANALE, Sara MATTIA.

*PhD students* Fabio D'ANDREAGIOVANNI, Carla MICHINI.

*Visitors* Renato BRUNI.

**Telecommunication network design and location** *Wireless network planning* A wireless network consists of a set of base stations distributed over a number of sites in order to provide connectivity to a set of customers' equipments located in a target region. In [13] and [14] we present the first mathematical formulation to optimize base stations location and configuration of WiMAX networks: a Mixed-Integer Linear Programming model is discussed in details and tested on several realistic instances. In [11] we present Power-Indexed formulation, a new approach to model and solve general wireless network planning problems by discretizing the emitted power range and associating boolean variables with discrete power levels: we reduce the problem to a pure Binary Linear Programming Problem, where sources of numerical instability of traditional planning formulations are removed.

*Power assignment* The Power Assignment Problem (PAP) is the problem of assigning transmission powers to the transmitters of a wireless network so as to maximize the satisfied demand. This problem has relevant practical applications in both radio-broadcasting and mobile telephony. Typical solution approaches make use of mixed integer linear programs with huge coefficients in the constraint matrix yielding numerical inaccuracy and poor bounds. In order to overcome these inconveniences, in [12] we developed a two-phase heuristic to solve large instances of PAP, namely a constructive heuristic followed by an improving local search.

*Television broadcasting network planning* Optimization plays a fundamental role in network design and planning, especially in the case of television broadcasting network. Here the maximum coverage has to be guaranteed along with the minimum spectrum requirement. In [4] we discuss the problem of optimizing artificial time-offsets in DVB broadcasting and show how this can be reduced to a classical combinatorial optimization problem, namely the hitting set problem. In

[16] we discuss different issues concerning the general problem and model the problem as an optimization problem for which well known and efficient solution algorithms have been proposed.

**Job-shop scheduling problems** These problems were studied in the context of train scheduling and routing. In [15] we develop a new Branch&Bound algorithm for real-time traffic control in terminal metro stations. In particular, we study a new and effective bounding procedure, which allows to solve to optimality within the one second time limit imposed by the application, several hundreds of job shop instances arising in the automatic traffic control in Milan metro system.

**Computational biology and polymer sequencing** Several computationally demanding problems arise from biological and medical research. Particularly relevant are the problems of sequence analysis, for peptides or for general polymers. Data obtained from the mass spectrometry analysis of a polymer, constituted, according to specific chemical rules, by an unknown sequence of monomers, should be processed in order to determine such sequence. By formulating a mathematical model for such combinatorial problem, structural limitations of known methods are overcome, and efficient solution algorithms based on combinatorial optimization are presented in [3]. Moreover, spectrometry data can be used to build a propositional logic formula, whose models represent coherent interpretations of the set of data and can be used to generate all possible correct results of the analysis itself [1, 8].

**Data mining and universe selection problems** Data mining is in general the process of extracting useful information from large amount of data. In particular, a crucial task in many statistical investigations is the so called Universe Selection step, that is finding the set of units that should be used for a survey. From a conceptual point of view, there is a very large set of units that could be surveyed. Surveying each one has a cost and represents a different portion of the whole situation that should be surveyed. One would like to choose a subset of units producing the minimum total cost for being surveyed and representing at least a certain total portion of the whole situation. A combinatorial optimization structure is therefore present [7]. By using binary variables associated with the above units, the problem is modeled in [5, 6] as a multidimensional binary knapsack problem.

**Satisfiability** Propositional satisfiability (SAT) is a central problem in many different fields, e.g. Artificial Intelligence, Cryptography, Database Systems, logic circuit design and testing. Moreover, SAT carries considerable theoretical interest as the original NP-complete problem. Therefore, the study of practically efficient algorithm for solving such problem is very important. A computational evaluation and comparison of a new family of conflict-based branching heuristics for evolved DPLL SAT solvers is reported in [2]. Such family of heuristics is based on the use of new scores updating criteria developed in order to overcome some of the typical unpleasant behaviors of DPLL search techniques.

**Cardinality constrained optimization** Cardinality constraints appear in a large number of applications, as diverse as finance, bioinformatics, and data mining. While such applications reside in the core of our economy and welfare, optimization problems with cardinality constraints are among the hardest ones in the field of operations research. In [9] we present a polyhedral study of linear optimization with cardinality constraints. In addition, we present a branch-and-cut algorithm to tackle large-scale optimization problems with cardinality constraints. In [10] we apply the algorithm to the problem of maximizing sparsity of large-margin classifiers used in supervised machine learning.

### Journals

- [1] Bruni R., Solving Peptide Sequencing as Satisfiability, *Computer and Mathematics with Applications*, Vol. 55(5), 912-923, 2008.
- [2] Bruni R., Santori A., New Updating Criteria for Conflict-Based Branching Heuristics in DPLL Algorithms for Satisfiability, *Discrete Optimization* Vol. 5(3), 2008.
- [3] Bruni R., A Combinatorial Optimization Approach for Determining Composition and Sequence of Polymers, *Algorithmic Operations Research*, Vol. 3(2), 2008.
- [4] Mannino C., Rossi F., Sassano A., Smriglio S., The time-offset optimization problem in digital broadcasting, *Discrete Applied Mathematics*, 156 (3), 339-351, 2008.

### Conference proceedings

- [5] Bianchi F., Bianchi G., Bruni R., Esposito N., Lorenzini F., Reale A., Ruocco G., A methodological approach for determining eligible units in the 2010 Italian Agricultural Census, *Proceedings of SIS2008*, Cosenza, Italy, 2008.
- [6] Bianchi F., Bianchi G., Bruni R., Esposito N., Lorenzini F., Reale A., Rocco G., Criteri e metodi per la determinazione ex-ante del campo di osservazione del Censimento dell'Agricoltura 2010, *IX Conferenza Nazionale di Statistica*, Roma, Italy, 2008.
- [7] Bruni R., Bianchi F., Bianchi G., Reale A., Cutting Planes for Surveying Italian Agriculture and Industry, *Proceedings of the XXXIX AIRO conference*, Ischia, Italy, 2008.
- [8] Bruni R., A Logic-Based Approach to Polymer Sequence Analysis, *Proceedings of EURO conference on Computational Biology, Bioinformatics and Medicine*, Roma, Italy, 2008.
- [9] Canale S., de Farias I. R., Zhao M., A cutting plane approach to cardinality constrained optimization, *Proceedings of the XXXIX AIRO conference*, 2008.
- [10] Canale S., de Farias I. R., Zhao M., A cutting plane approach to 0-norm optimization, *Proceedings of the INFORMS Annual Meeting*, 2008.
- [11] D'Andreagiovanni F., Mannino C., Sassano A., Power-Indexed Formulation for WiMAX Network Planning, *Proceedings of the XXXIX AIRO conference*, 2008.
- [12] Mannino C., Mattia S., Sassano A., Planning Wireless Networks by Shortest Path, *Proceedings of the XXXIX AIRO conference*, 2008.

### Submitted papers, technical reports and others

- [13] D'Andreagiovanni F., Mannino C., A MILP Formulation for WiMAX Network Planning, Tech. Rep. TR02-08, Dipartimento di Informatica e Sistemistica, Università di Roma "Sapienza", 2008.
- [14] D'Andreagiovanni F., Mannino C., An Optimization Model for WiMAX Network Planning, *WiMAX Network Planning and Optimization*, Auerbach Publications, to appear.
- [15] Mannino C., Mascis A., Optimal Real-Time Traffic Control in Metro Stations, *Operations Research*, to appear.
- [16] Rossi F., Sassano A., Smriglio S., Il percorso più breve per vedere la TV, Editors Giorgio Ausiello, Rossella Petreschi, Mondadori Sapienza, to appear.

### 3.3.2 Industrial Economics

This group has devoted attention to the theoretical explanations and empirical implications of some interrelated issues: (i) technological innovation, (ii) strategic behavior of Multinational Enterprises (MNE), (iii) national and multilateral policies on foreign direct investment (FDI) and innovation, (iv) environmental policy and foreign direct investment. 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; Université Lille 1, France; Norwegian Institute of Foreign Affairs (NUPI), Norway.

#### *Group members*

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

**Environmental policy and foreign direct investment** This is the first step in a longer term project on the effects of asymmetric environmental policies on the international strategies of firms, when countries differ in terms of market size and barriers to trade and FDI have been removed. This research stream contributes to the debates on the Pollution Haven Hypothesis and on the risk of "carbon leakage" in the EU. A simple monopoly model with endogenous plant location has been developed, considering both a symmetric and an asymmetric scenario. It is shown that, in an asymmetric context, if the more stringent environmental policy is introduced by the larger country and unit transport cost is high with respect to the pollution tax, it is possible that the firm's location choice will not change. The model suggests that environmental taxes should be industry-specific, accounting for the geographical mobility of the industry. We are also planning to expand the model considering an oligopolistic market structure and endogenizing firms' research activity [3], [7].

**R&D international production and asymmetries in knowledge transmission** Several topics have been analysed. The first strand of research investigates the interaction between firms' international strategy and innovative performance by employing a dynamic oligopoly model and under the assumption that knowledge flows increase with geographical proximity. 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 [6]. We also dealt with other sources of asymmetry such as unequal know-how management capabilities within a static game theoretical framework. We found that a better ability to manage knowledge flows stimulates the firm to invest more in R&D. Moreover, introducing geographically bounded spillovers, we also showed that one-way FDI stimulates the MNE to raise its own R&D, and that FDI is more likely to occur when geographical proximity increases the MNE's capability to source local know-how [1].

**Cross-border mergers and acquisitions and technology transfer** This line of research aimed at identifying the optimal FDI mode (greenfield investment versus acquisition) in a two-country, two-firm Cournot model with differing technological levels and country sizes, thus 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 [2], [4].

**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 [5].

**Underprovision of quality and regulation** Another line of research has aimed at modelling the behaviour of sellers in a market for an experience good, where it is impossible 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 [8].

### Articles in books

- [1] Petit, M.L., Sanna-Randaccio F. and Sestini R. R&D and foreign investment with asymmetries in knowledge transmission. In M.P. Feldman and G.D. Santangelo, editors, *New Perspectives in International Business Research*. Emerald Group Publishing Limited, Bingley U.K., 2008.

### Conference proceedings

- [2] Grunfeld, L. and Sanna-Randaccio, F. Who buys whom in international oligopolies with FDI and technology transfer? In *Conference Proceedings, International Economic Association 15th World Congress*. Istanbul, Turkey, June 25-29, 2008.

- [3] Sanna-Randaccio F. and Sestini R. Foreign direct investment and environmental policy: have location factors been neglected? In *Proceedings of the EIBA 34th Annual Conference*. University of Tallinn, Estonia, December 11-13, 2008.

### Submitted papers, technical reports and others

- [4] Grunfeld, L. and Sanna-Randaccio, F. Who buys whom in international oligopolies with FDI and technology transfer? Submitted.
- [5] Iammarino, S., Sanna-Randaccio, F. and Savona, M. The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. Submitted.
- [6] Petit, M.L., Sanna-Randaccio, F. and Sestini, R. Asymmetric knowledge flows and localization with endogenous R&D: a dynamic analysis. Forthcoming in *Economic Modelling*.
- [7] Sanna-Randaccio F. and Sestini R. Foreign direct investment and environmental policy: have location factors been neglected? Technical Report n. 04–08, Dipartimento di Informatica e Sistemistica, "A. Ruberti", Università di Roma "La Sapienza", 2008.
- [8] 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;
- 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 research project 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.

**Regulation and competition in the pharmaceutical industry** International arbitrage, or parallel trade (PT), is widely argued to reduce firms investment in product quality, since it dampens price discrimination. Conversely, we show that, if the domestic and the re-imported products are imperfect substitutes, then firms may raise investment to effectively control PT. We find that investment and worldwide consumer surplus with PT may simultaneously increase. Thus, the conflict between static and dynamic efficiency related to the exhaustion regime of intellectual property rights is diluted. Finally, we show that PT does not affect investment under foreign market regulation, since the price incorporates the firms opportunity cost of selling abroad [7].

**Regulation and competition in network industries** We analyze the impact of regulation on network investment. In [6], we show that a multi-period schedule where regulated access charges rise over time is critical to foster efficient competitive network investment. In [2], [4], we study the effect of vertical separation of the telecommunications incumbent when the access network is an enduring economic bottleneck. We show that, despite efficiency losses of vertical disintegration, separation may improve investment and welfare. The relevance of these issues carries over to the prospective deployment of the Next Generation Access networks. In [3], we analyze how an incumbent firm can strategically bundle services to prevent competition to the extent that foreclosure of entrant firms may occur; in such cases either the regulator or the antitrust agency should consider prohibiting bundling. We show that applying a price squeeze test which suitably incorporates the entrants additional costs to provide quality can improve welfare compared with a ban on bundled offers.

**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. Dealing with this type of auction involve hard optimization problems, that require specific solution techniques [5].

**Multicriteria managerial decision making** Our research illustrates the advantages of the multicriteria methodology applied to managerial decision making problems. In [1] 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., Bertolazzi P., Batini C., Missier P. Brokering infrastructure for minimum cost data procurement based on quality - quantity models. *Decision Support Systems*, 45, pp. 95-109, 2008.

## Articles in books

- [2] Leporelli C. Next Generation Networks: caratteristiche tecnologiche e problematiche concorrenziali. In *La tripla convergenza*, a cura di A. Castaldo, S. da Empoli, Carocci.

## Conference proceedings

- [3] Avenali A., D'Annunzio A. and Reverberi P. Bundling and entry deterrence in communications markets. *19th European regional conference of the International Telecommunications Society (ITS)*, Rome, Italy, 18-20 September 2008.
- [4] Avenali A., Matteucci G. and Reverberi P. Vertical Separation and Network Investment in Telecommunications. *Proceedings of the Telecom Paristech Conference On the Economics Of ICT*, Paris, France, 19-20 June 2008.

## Submitted papers, technical reports and others

- [5] Avenali A. Exploring the VCG Mechanism in Combinatorial Auctions: the Threshold Revenue and the Threshold-Price Rule. *European Journal of Operational Research*, Accepted for publication, 2008.

- [6] Avenali A., Matteucci G. and Reverberi P. Dynamic access pricing and incentives to invest in alternative infrastructures. Submitted, 2008.
- [7] Matteucci G., Reverberi P. Parallel trade, quality investments and regulation. Submitted, 2008.

### 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.

The members of the group are: Luca BENVENUTI, Alberto DE SANTIS and Lorenzo FARINA (Faculty members)

**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). Hybrid systems are useful abstractions of embedded controllers. However, they are notoriously very difficult to verify as computation complexity grows quickly with the size of the hybrid system. We address the problem of building in a systematic way a compact representation of a hybrid system obtained by composing hybrid

subsystems. This technique can be used as a front-end to any hybrid formal verification tool thus freeing the designer from the cumbersome and error-prone manual calculation of the composition and of its reduction. Critical to the efficiency of the method are: i) hiding the internal signals and synchronization events between components; ii) eliminating locations that result in empty invariant conditions as well as non reachable locations; iii) computing an equivalent minimal realization of the composed hybrid system.

The publications relevant to this area are: [6, 7, 8, 9].

**Computational optimization in systems biology** Recent advances in molecular biology (including the most recent Nobel prizes research) have shown the fundamental role played by the regulation of mRNA abundance in the cell after transcription. We have investigated post-transcriptional regulation in gene expression dynamics. We have shown that in the metabolic cycle of *S. cerevisiae* the role of the PUF-family proteins is like a driving force able to precisely modulate and control mRNA abundance in the cell during each metabolic cycle, [5]. Moreover, we developed a model based distance measure between pairs of gene expression time profiles, which includes the presence of a post-transcriptional regulation at the mRNA stability level. Using this new approach we were able to correctly identify, in the reproductive cell cycle of *S. cerevisiae*, a large number of genes transcriptionally co-regulated by means of a common transcription factor, [4].

The publications relevant to this area are: [4, 5, 10, 12, 11].

**Signal processing and computer vision** The image segmentation provides a simplified version of the original image retaining all the information relevant to the considered application. The local structure of segmented images may assume a finite number of configuration that constitutes an alphabet. Neural network classifier can be trained to recognize these patterns on real world images and quickly provide the segmentation for real time applications [2]. Segmentation allows quantitative analysis of objects shape, providing a versatile tool for the analysis in the Science of materials [3, 4].

The publications relevant to this area are: [2, 1, 3, 13, 14, 15, 16].

## Journals

- [1] 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*, 196, 292-302, 2008.
- [2] De Santis A., Iacoviello D., Discrete image modelling for piecewise constant segmentation of images by artificial neural networks, *IET Image Processing*, 10:2, 125-133, 2008.
- [3] De Santis A., Iacoviello D., Di Cocco V., Di Bartolomeo O., Un approccio innovativo per l'analisi quantitativa delle superfici di frattura e fatica nelle ghise sferoidali mediante elaborazione delle immagini, *Frattura e Integrità Strutturale*, 5, 27-38, 2008.
- [4] Farina L., De Santis A., Salvucci S., Morelli G. and Ruberti I., Embedding mRNA stability in correlation analysis of time-series gene expression data, *PLoS Computational Biology*, 1, 10-17, 2008.
- [5] 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*, 275, 1742-1758, 2008.

### Articles in books

- [6] Benvenuti L., Ferrari A., Mazzi E., Sangiovanni-Vincentelli A., Contract based design for computation and verification of a closed-loop hybrid system Lecture Notes in Computer Science 4981, M. Egerstedt and B. Mishra Eds., Springer, 58-71, 2008.

### Conference proceedings

- [7] Benvenuti L., Bresolin D., Casagrande A., Collins P., Ferrari A., Mazzi E., Sangiovanni-Vincentelli A., Villa T., Reachability computation for hybrid systems with Ariadne 17th IFAC World Congress, Seoul, South Korea, 2008.
- [8] Benvenuti L., Ferrari A., Mangeruca L., Mazzi E., Passerone R., Sofronis C., A contract-based formalism for the specification of heterogeneous systems Forum on Specification & Design Languages, Stuttgart, Germany, 2008.
- [9] Benvenuti L., Ferrari A., Mazzi E., Sangiovanni-Vincentelli A., Composing hybrid systems 47th Conference on Decision and Control, Cancun, Mexico, 2008.
- [10] Farina L., Leads and lags: gene relationships beyond co-expression BiCi workshop on Biological Networks: Modelling, Analysis and Integration, Betinoro, Italy, September 16-20, 2008.
- [11] Farina L., Germani A., Mavelli G., Palumbo P., Prediction of gene regulatory network motifs using the expression time course of targets genes Mini Euro Conference on Computational Biology, Bioinformatics and Medicine, Rome, Italy September 15-17, 2008.
- [12] Farina L., Grippo L., Lucidi S., Paziienza G., Radial basis functions for the identification of cell cycle regulated genes in human cancer cells Mini Euro Conference on Computational Biology, Bioinformatics and Medicine, Rome, Italy September 15-17, 2008.

### Submitted papers, technical reports and others

- [13] 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*, in press.
- [14] De Santis A., Iacoviello D., A robust eye tracking procedure for medical and industrial applications Computational Methods in Applied Sciences of SPRINGER, *Advances in Computational Vision and Medical Images*, 5, 27-38, in press.
- [15] De Santis A., Iacoviello D., Robust real time eye tracking for computer interface for disabled people, *Computer Methods and Programs in Biomedicine*, submitted.
- [16] De Santis A., Iacoviello D., Region growing methods for medical images segmentation, *International Journal of Tomography and Statistics*, submitted.

### 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 2008, the Nonlinear Optimization group has been mainly involved in the MIUR-PRIN National Research Program "Problemi, metodi e algoritmi innovativi nell'Ottimizzazione Non-lineare".

#### *Group members*

*Faculty members* Gianni DI PILLO, Francisco FACCHINEL, 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, a new truncated Newton method for large scale unconstrained optimization has been proposed, with the distinguishing feature of determining, at each iteration, a pair of search direction: the first approximates the Newton step of the quadratic convex model, while the second is a suitable negative curvature direction. Then, a test based on the quadratic model of the objective function is used to select the most promising between the two search directions. The resulting algorithm is globally and superlinearly convergent to second order critical points. [6].

Moreover, derivative-free optimization has been considered, too. An additional difficulty arises from the fact that it is assumed that the derivatives of the functions involved in the problem definition are not available. In this framework, a method which includes a geometry phase whose goal is to ensure the adequacy of the interpolation set has been proposed in [7] and a derivative-free algorithm for the solution of nonlinear systems of inequalities has been considered in [3].

Finally, a new Conjugate Gradient based algorithm has been proposed for the solution of symmetric linear systems by extending some standard theoretical properties of the Conjugate Gradient method [5].

**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 [4].

Nonlinear programming problems arising as formulations of low rank Semidefinite Programming (SDP) problems have been considered [9, 8]. They are important relaxations of the max cut problem on a graph. A globally convergent algorithm has been defined and tested on max cut problems available in literature. Moreover the standard linear SDP problem and its low rank nonlinear programming reformulation based on a Gramian representation of a positive semidefinite matrix have been considered and for this nonconvex quadratic problem with quadratic equality constraints, necessary and sufficient conditions of global optimality have been given.

**Equilibrium problems** Another topic of interest was the study of Generalized Nash Equilibrium Problems (GNEP). GNEPs are a variant of the usual Nash Equilibrium Problem wherein the feasible sets of the players depend on the other players' strategies. A novel GNEP model for the

power allocation with rate constraints in telecommunications has been proposed in [1]. 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** The research in global optimization focused of the solution of difficult large scale problems. In particular, drawing the inspiration for the well known DIRECT algorithm, a new multi-start algorithm using DIRECT as a deterministic generator of starting point has been defined. The new algorithm actually consists in repeatedly applying the multi-start algorithm on suitable modifications of the variable space that exploit the information gained during the optimization [10].

**Applications** An important aspect of the research concerned the definition of optimization algorithms for solving problems arising from real world applications. In particular, [2] deals with a model used in epidemiology.

## Journals

- [1] Facchinei F., Pang J.-S., Scutari G. , and Wang C. Distributed power allocation with rate constraints in Gaussian parallel interference channels. *IEEE Transaction on Information Theory*, 54:3471–3489, 2008.
- [2] Iacoviello D. and Liuzzi G. Fixed/free final time SIR epidemic models with multiple controls. *International Journal of Simulation and Modeling*, 2:81–92, 2008.
- [3] Liuzzi G. and Lucidi S. A derivative-free algorithm for systems of nonlinear inequalities. *Optimization Letters*, 2:521–534, 2008.

## Submitted papers, technical reports and others

- [4] Di Pillo G., Liuzzi G., Lucidi S., and Palagi L. A truncated Newton method in an augmented Lagrangian framework for nonlinear programming. To appear in *Computational Optimization and Applications*.
- [5] Fasano G. Notes on a 3-term conjugacy recurrence for the iterative solution of symmetric linear systems. Technical Report 179/2008, Università Ca Foscari, Venice, 2008.
- [6] Fasano G. and Lucidi S. A nonmonotone truncated newton-krylov method exploiting negative curvature directions, for large scale unconstrained optimization: complete results. Technical Report 2008–035, INSEAN, Roma, 2008. Submitted to *Optimization Letters*.
- [7] Fasano G., Morales J.L., and Nocedal J. On the geometry phase in model-based algorithms for derivative-free optimization. To appear in *Optimization Methods and Software*.
- [8] Grippo L., Palagi L., and Piccialli V. Necessary and sufficient global optimality conditions for NLP reformulations of linear SDP problems. To appear in *Journal of Global Optimization*.
- [9] Grippo L., Palagi L., and Piccialli V. An unconstrained minimization method for solving low rank SDP relaxations of the max cut problem. To appear *Mathematical Programming*.
- [10] Liuzzi G., Lucidi S., and Piccialli V. A DIRECT-based approach exploiting local minimization for the solution of large-scale global optimization problems. To appear in *Computational Optimization and Applications*.