DIS - Research groups

Algorithm Engineering
Artificial Intelligence
Communication Networks
Data and Knowledge Bases
Distributed Software Architectures
Distributed Systems
Parallel and Distributed Computing
Programming Languages and Methodologies

Biomedical Systems
Hybrid Systems
Identification and Optimal Control
Nonlinear Systems
Robotics

Combinatorial Optimization
IndustrialEconomics
Industrial Organization and Management
Modelling, Data Analysis and Optimization
Nonlinear Optimization

Dipartimento di Informatica e Sistemistica
Antonio Ruberti
http://www.dis.uniroma1.it

ISBN 978-88-548-1064-8

Research report 2006

DIPARTIMENTO DI INFORMATICA
E SISTEMISTICA ANTONIO RUBERTI

SAPIENZA
UNIVERSITÀ DI ROMA

Research report 2006

ARACNE Dipartimento di Informatica e Sistemistica Antonio Ruberti

www.aracneeditrice.it
info@aracneeditrice.it

via Raffaele Garofalo, 133 A/B
00173 Roma
(06) 93781065

ISBN 978–88–548–1064–8

Cura e composizione: Luigia CARLUCCI AIELLO
Claudio DE PERSIS
Immagine di copertina: Attilio CRISTINI
Grafica di copertina: Anna Paola DI RISIO

I edizione: marzo 2007

Dipartimento di Informatica e Sistemistica Antonio Ruberti
Sapienza Università di Roma

Research report 2006

Dipartimento di Informatica e Sistemistica Antonio Ruberti

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

DIS-Eudossiana
Via Eudossiana 18, 00184 Roma, Italia
Phone +39 06 44585360
Fax +39 06 44585367

DIS-Buonarroti
Via Buonarroti 12, 00185 Roma, Italia
Phone +39 06 482991
Fax +39 06 47825618

DIS-Salaria
Via Salaria 113, 00198 Roma, Italia
Phone +39 06 49918487
Fax +39 06 85300849

DIS is about to move to the building shown on the front cover, located at Via Ariosto 35, 00184 Roma.

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

Contents

1 Introduction

The present report provides an overview of the research carried out at the Department of Computer and Systems Science Antonio Ruberti (DIS) of the Rome University Sapienza, during the year 2006.

DIS was established in 1983 as an evolution of the Istituto of Automatica; in 2001 it was named after Antonio Ruberti, the eminent scholar who founded it.

DIS is a center for research and education at the undergraduate and graduate levels. Strong research groups exist in computer, systems, and management sciences. Basic research is the main goal of DIS, with a strong emphasis on interdisciplinary research, on applications that stimulate basic research, and with a specific attention to technology transfer and dissemination of results.

Collaborations are maintained with researchers in other university departments, research institutions and companies, in Italy and abroad.

The main educational goal is to prepare students for professional, research and teaching careers either in universities or in industries in information technologies, automation, and management.

The faculty of DIS in 2006 consists of 32 full professors, 19 associate professors, and 13 assistant professors (ricercatori). They provide education at the undergraduate and graduate levels to several programs of the School of Engineering at Sapienza, with main responsibility in the curricula in informatics, systems and control sciences, and management. The teaching activity is not illustrated in this report; a description may be found be found at `http://www.dis.uniroma1.it/students.html`

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

The main research areas of DIS are:

- Computer science
- Systems science
- Management science

This is reflected in the structure of Section 3, where the main research lines are described for each area, together with the list of people involved, and the collection of publications appeared in 2006.

2 General Information

2.1 Location

The present locations of DIS are:

DIS-Eudossiana
Via Eudossiana 18, 00184 Roma
Phone +39 06 44585358, Fax +39 06 44585367
Administration and Head offices
DIS Library
Robotics laboratory, Systems and control laboratory
Systems science research groups.

DIS-Buonarroti
Via Buonarroti 12, 00185 Roma
Phone +39 06 482991, Fax +39 06 47825618
Operations research laboratory
Combinatorial optimization, Nonlinear optimization, Industrial economics, and Industrial organization and Management research groups.

DIS-Salaria
Via Salaria 113, 00198 Roma
Phone +39 06 49918487, Fax +39 06 85300849
Computer science laboratory
Computer science research groups.

DIS is about to move to the building shown in the front cover, located at Via Ariosto 35, 00184 Roma.

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. Approximately 11,000 books and conference proceedings, plus 392 journals subscriptions (94 of which active), and 784 on-line journals are currently available. The DIS library provides the department with access to information in its many formats in order to support teaching, learning, research, and service functions. The library facilities are also available to non-members of the Department, and students.

The library provides resources and services in an environment that fosters free and open enquiry, and serves as a catalyst for the interpretation, integration and application

of knowledge in learning and research. It also fosters the cultural growth in the department and in the wider community.

During the year 2006, 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 2006 were: Mario BOLOGNANI, Giovanni CARRADA, Carlo CELLUCCI, Enrico BELLONE, and Michele EMMER.

Research laboratories

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

ALCOR: Autonomous Agent Laboratory for Cognitive Robotics – The laboratory is devoted to develop autonomous systems for operating in unstructured and rescue environments, as well as vision based security systems.
Person in charge: Fiora PIRRI.
Location: DIS-Salaria. Web: `http://www.dis.uniroma1.it/~alcor`

DAMSO: Integrative Modelling, Simulation, Data Analysis and Optimization – The laboratory aims at developing models and testing efficient algorithms for processing real world data from industrial and biosystems engineering.
Person in charge: Alberto DE SANTIS.
Location: DIS-Buonarroti.

DASI Lab: Data and Service Integration Laboratory – The laboratory is devoted to the development of software research prototypes for service-based and data-integration distributed systems.
Person in charge: Maurizio LENZERINI.
Location: DIS-Salaria. Web: `http://www.dis.uniroma1.it/~dasilab`

Network Control Laboratory – The laboratory is devoted to the design, simulation, and experimental validation of advanced resource management procedures for wireless networks.
Person in charge: Francesco DELLI PRISCOLI.
Location: DIS-Eudossiana.

MIDLAB: MIDleware LABoratory – 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.
Person in charge: Roberto BALDONI.
Location: DIS-Salaria. Web: `http://www.dis.uniroma1.it/~midlab`

Operations Research Laboratory – The laboratory is devoted to the development of mathematical models and algorithms for the solution of mathematical programming problems.
Person in charge: Massimo ROMA.
Location: DIS-Buonarroti.

Robotics Laboratory – The laboratory is devoted to the development and experimental validation of advanced planning and control techniques for industrial and service robots.
Person in charge: Giuseppe ORIOLO.
Location: DIS-Eudossiana. Web: `http://www.dis.uniroma1.it/~labrob`

SIED: Intelligent Systems for Emergencies and Civil Defense – The laboratory stemmed from a collaboration between "Istituto Superiore Antincendi" and DIS, with the goal to develop methodologies, techniques and tools to be used in rescue operations.
Person in charge: Daniele NARDI.
Location: Via del Commercio, 13 (Istituto Superiore Antincendi) Roma.
Web: `http://www.dis.uniroma1.it/multirob/sied`

Systems and Control Laboratory – The laboratory is devoted to the development and experimental verification of new control strategies.
Person in charge: Salvatore MONACO.
Location: DIS-Eudossiana. Web: `http://sistemi.ing.uniroma1.it/`

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

Educational laboratories

DIS manages two educational laboratories of the School of Engineering, used for hands-on teaching and in 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/studlabs.html`

Computer Science Laboratory Paolo Ercoli for introductory courses – About 150 stations are available for undergraduate teaching.
Person in charge: Giacomo CIOFFI.
Location: Via Tiburtina 205, Roma.

PC and Workstations Laboratory Paolo Ercoli for advanced courses – About 75 PC and workstations are available for the graduate teaching.
Person in charge: Umberto NANNI.
Location: Via Eudossiana 18, Roma.

2.3 People

Director

Gianni DI PILLO, till October 31st, 2006
Luigia CARLUCCI AIELLO, since November 1st, 2006

Administration head

Maria Pia VANDILLI

Faculty

Professors

On November 21st, 2006, Marco CADOLI passed away. We here honor his memory: A dedicated professor, a distinguished scientist, and one of the earliest researchers of the Artificial Intelligence group at DIS.

Giorgio AUSIELLO
Roberto BALDONI
Stefano BATTILOTTI
Carlo BRUNI
Marco CADOLI
Luigia CARLUCCI AIELLO
Tiziana CATARCI
Bruno CICIANI
Giacomo CIOFFI
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
Giorgio MATTEUCCI
Massimo MECELLA
Roberta SESTINI
Marilena VENDITTELLI

Contract professors

Fabio CELANI

Staff

Research associates and post docs

Enrico BERTINI
Andrea CAPOCCI
Carlos CASTILLO OCARANZA
Loredana DE GIOVANNI
Fabio DE ROSA
Debora DONATO
Alessandro FARINELLI
Tiziano INZERILLI
Kleoni IOANNIDOU
Stephen KIMANI
Giampaolo LIUZZI
Michele MASTROGIOVANNI
Raffaella MATTONE
Fabio MITRANO
Raffaele NICOLUSSI
Veronica PICCIALLI
Antonio PIETRABISSA
Antonella POGGI
Damiano POZZI
Vivien QUEMA
Ruggero RUSSO
Gianfranco SANTORO
Monica SCANNAPIECO
Francesco SCIALACQUA
Vito SERVEDIO
Sara TUCCI PIERGIOVANNI
Antonino VIRGILLITO
Andrea VITALETTI

Administration staff

Amelia ARRICALE
Antonietta CANGELLI
Beatrice DE CARLO
Maria Grazia GIACON
Tiziana VALENTINI
Maria Pia VANDILLI

Technical staff

Sergio BALDINI (until January 2006)
Giuseppe CAPOZI
Mauro CICCI
Anna Paola DI RISIO
Giuseppe FILACI
Tiziana TONI

Auxiliary services

Pia BONANNI
Antonio SIMEONI

Librarian

Laura ARMIERO

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

2.4 Doctoral programs

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

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)

XIX course

ASTOLFI Laura

Computer engineering

The council of professors of the Ph.D. program in Computer engineering is coordinated by Maurizio LENZERINI.
The research topics are: Theory of algorithms, computer systems, databases, programming languages, theoretical computer science, image processing, artificial intelligence, cognitive robotics, VLSI, computational logics, performance evaluation,distributed software architectures, computer networks, and security.

Ph.D. students

XIX course	XX course	XXI course	XXII course
ALULLI Luca	ADNAN NOOR Mian	BELARDINELLI Anna	ACCATTOLI Beniamino
BONIFACI Vincenzo	CHIRICHELLO Antonella	DE LEONI Massimiliano	BLOISI Domenico
MILANI Alessia	FRATARCANGELI Marco	MARCHETTI Luca	BONOMI Silvia
MILANO Diego	RIBICHINI Andrea	PASCUCCI Alessio	BORDINO Ilaria
PECORA Federico	UGAZIO Giorgio	PATRIZI Fabio	CALISI Daniele
POGGI Antonella	ZIPARO Vittorio Amos	SCIPIONI Sirio	LAMANNA Domenico
QUERZONI Leonardo		SETTEMBRE Giuseppe Paolo	MICALETTO Davide
ROMANO Paolo		TIPALDI Gian Diego	PELLEGRINI Stefano
RUZZI Marco			

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
RISI Arnaldo	RINALDI Francesco

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

XIX course	XX course	XXI course	XXII course
CINAT David	BALDESI Gianluca	FABBRI Filippo	ASNAGHI Simone
FERRONE Claudia	CAVARISCHIA Leonardo	GABRIELE Simone	CASTRUCCI Marco
FREDA Luigi	CHERUBINI Andrea	MAGNANTI Silvano	DI GIORGIO Alessandro
GUAINELLA Emiliano	ROBUFFO GIORDANO Paolo	MERCURIO Andrea	FRANCHI Antonio
MARCHETTI Ilaria	SURACI Vincenzo		GENTILI Enrico
SANTORO Gianfranco			
USAI Andrea			

2.5 Contracts

DIS carries on its research on contracts with public funding agencies and companies. Some of them go on over more than one year. We herewith report only the research contracts signed in the year 2006. The titles of the contracts with Italian bodies are reported in Italian.

Contracts with the European Union

Contractor	Value (euro)	Title	Project Leader
E.U.	100.237	VIEW-FINDER, Vision and Chemiresistor Equipped Web-connected Finding Robots	F. Pirri
E.U.	240.000	SEMANTICGOV, Providing Integrated Public Services to Citizens at the National and Pan-European level with the use of Emerging Semantic Web Technologies	R. Baldoni
E.U.	195.489	PHRIENDS, Physical Human-Robot Interaction: depENDability and Safety	A. De Luca
E.U	160.335	Resilience for Survivability in IST	R. Baldoni
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

Contracts with Italian research institutions

Contractor	Value (Euro)	Title	Project Leader
MIUR	39.800	Problemi e Metodi Innovativi nell'Ottimizzazione Nonlineare	G. Di Pillo
IRPPS-CNR	24.000	Tecniche di data mining per classificazione e interrogazione delle basi di dati; Requisiti per il middleware e tecniche di data mining	U. Nanni
MIUR	225.000	Tecnologia e Scienza per le reti di prossima generazione	A. Marchetti Spaccamela
Istituto Superiore di Sanità	10.000	Sistema informativo dei dati riferiti ad intossicazioni acute da antiparassitari	A. Marchetti Spaccamela

Contracts with companies

Contractor	Value (Euro)	Title	Project Leader
Archimedes Logica Srl	28.000	Sviluppo di tecniche di elaborazione delle immagini per il tracciamento di oggetti in movimento per il monitoraggio, sorveglianza, gestione e controllo del traffico di natanti in un canale navigabile	L. Iocchi
Alcatel Alenia Space	17.475	Definizione di piani/procedure e supporto all'esecuzione delle prove di compatibilità elettromagnetica e delle prove in volo del terminale SATCOM installato sull'elicottero NH90 (tipo TTH)	F. Delli Priscoli
TERNA Rete Elettrica Nazionale	50.000	Attività Specialistica inerente funzioni di analisi per sistema WAMS di TERNA	S. Monaco
Galileo Avionica Spa	37.533	Studio relativo all'elaborazione e fusione dati provenienti dai sensori elettro-ottici integrati FLIR-OWS	F. Pirri
Galileo Avionica Spa	38.000	Studio relativo alla stabilizzazione elettronica dei sensori elettro-ottici	F. Pirri
Alcatel Alenia Space	52.060	Analisi e specifica della rete satellitare di tipo Critical Network Infracstructure (CNI) in ambito ferroviario nel progetto VECTOR-SAT	F. Delli Priscoli
Telecom Italia Spa	24.000	Metodologia di campionamento e di analisi degli stream di dati per il monitoraggio dell'accesso ai servizi di rete	S. Leonardi
Telecom Italia Spa	29.984	Analisi di reti Peer to Peer (p2p)	R. Baldoni

3 Research

3.1 Computer science

3.1.1 Algorithm Engineering

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

1. algorithms that perform efficiently in a dynamically changing environment;
2. models and methodologies for the analysis and design of algorithms for information retrieval;
3. the design and analysis of approximation algorithms for NP-hard optimization problems;
4. the design of on-line algorithms that work with incomplete information on the input instance;
5. the design and implementation of tools and platforms for the experimental analysis and visualization of the behavior of algorithms and data structures.

The achievements of the AE group are widely recognized.

Giorgio Ausiello is Editor in Chief of Theoretical Computer Science, Series A, Algorithms and Complexity and Member of the Editorial Board of the International Journal of Foundations of Computer Science (IJFCS) and of Computer Science Review. Finally, in 2006 Giorgio Ausiello was elected President of the European Association for Theoretical Computer Science. Stefano Leonardi was editor of the Journal of Interconenction Networks in the years 2004-2006. He was also guest Editor for the Journal of Internet Mathematics, in the special issue for the Workshop on Algorithmic and Numerical Aspects in Web Search. Alberto Marchetti-Spaccamela is currently President of the Italian chapter of EATCS and was editor of a special issue of Journal of Discrete Algorithms in honour of Giorgio Ausiello's 60th birthday.

Members of the AE group are continuously involved in the Program and Steering Committees of International Conferences.

Giorgio Ausiello has been and currently is in the steering committee of the European Symposium on Algorithms (ESA).

Alberto Marchetti-Spaccamela has been and currently is member of the steering committee of the Workshop on Graphtheoretic concept in Computer Science (WG) and of ATMOS. He was also in the Program Committee of WG 2006, of the International conference on Mathematical Foundations of Computer Science (MFCS) and of the workshop on Algorithmic Aspects of Wireless Sensor Networks (Algosensors).

Stefano Leonardi has been and currently is in the steering committee of the European Symposium on Algorithms (ESA). He was also in the Program Committee of the 33rd

International Colloquium on Automata, Languages and Programming (ICALP'06).

Camil Demetrescu is member of the Steering Committee of the ACM-SIAM Workshop on Algorithm Engineering and Experiments (ALENEX). He was in the Program Committe of the 5th International Workshop on Experimental Algorithms (WEA'06), the 4th Program Visualization Workshop (PVW'06) and the 6th Workshop on Algorithmic Methods and Models for Optimization of Railways (ATMOS'06).

Members of the group delivered invited lectures at international workshops in their research areas.

Camil Demetrescu delivered the following invited lecture: "Dynamic Shortest Paths" at the 19th International Symposium on Mathematical Programming, Federal University of Rio de Janeiro, Brazil, July 30 - August 4, 2006. Giorgio Ausiello delivered an invited talk at the Conference Theory and Applications of Models of Computation (TAMC), Beijing 2006. Luca Becchetti delivered the invited talk: at Bertinoro Workshop on Adversarial Modeling and Analysis of Communication Networks, November 26 - December 2, 2006.

A regular Seminar Program, the Interdepartmental Seminar on Algorithms (SIA), is organized in cooperation with the Department of Computer Science of our university (see `http://www.dis.uniroma1.it/sia/`).

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

The AE group is presently involved in the following research projects: ALENIA Spazio "Wideband Wireless Local Area Network" (WWLAN); EU Contract 001907 "Dynamically Evolving Large Scale Information Sytems" (DELIS); EU/IST Integrated Project IP-FP6-015964 AEOLUS, "Algorithmic Principles for Building Efficient Overlay Computers"; MIUR National Project "Algorithms for the Next Generation Internet and Web: Methodologies, Design and Application" (ALGO-NEXT); MIUR Firb international Italian-Israelian cooperation RBIN047MH9 project, started in September 2006.

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

Graphs and networks. In the area of graph and network algorithms major emphasis has been devoted to the analysis and design of algorithms for dynamically evolving graphs and networks and to their robustness with respect to topological properties and connectivity.

In [19] the authors present the results of an extensive computational study on dynamic algorithms for all pairs shortest path problems. They describe our implementations of the recent dynamic algorithms of King and of Demetrescu and Italiano, and compare them to the dynamic algorithm of Ramalingam and Reps and to static algorithms on random, real-world and hard instances. Their experimental data suggest that some of the dynamic algorithms and their algorithmic techniques can be really of practical value in many situations.

In [3] the authors present first fully dynamic algorithm for maintaining all pairs shortest paths in directed graphs with real-valued edge weights. Given a dynamic directed graph G such that each edge can assume at most S different real values, they show how to support updates in $O(n^{2.5}\sqrt{S\log^3 n})$ amortized time and queries in optimal worst-case time. This algorithm is deterministic: no previous fully dynamic algorithm was known for this problem. In the special case where edge weights can only be increased, they give a randomized algorithm with one-sided error that supports updates faster in $O(S\cdot n\log^3 n)$ amortized time. The authors also show how to obtain query/update tradeoffs for this problem, by introducing two new families of randomized algorithms. Algorithms in the first family achieve an update bound of $\widetilde{O}(S\cdot k\cdot n^2)$ and a query bound of $\widetilde{O}(n/k)$, and improve over the previous best known update bounds for k in the range $(n/S)^{1/3}\leq k<(n/S)^{1/2}$. Algorithms in the second family achieve an update bound of $\widetilde{O}\left(S\cdot k\cdot n^2\right)$ and a query bound of $\widetilde{O}(n^2/k^2)$, and are competitive with the previous best known update bounds (first family included) for k in the range $(n/S)^{1/6}\leq k<(n/S)^{1/3}$.

In [20] the authors survey fully dynamic algorithms for path problems on general directed graphs. In particular, they consider two fundamental problems: dynamic transitive closure and dynamic shortest paths. Although research on these problems spans over more than three decades, in the last couple of years many novel algorithmic techniques have been proposed. In this survey, the authors make a special effort to abstract some combinatorial and algebraic properties, and some common data-structural tools that are at the base of those techniques. This will help us try to present some of the newest results in a unifying framework so that they can be better understood and deployed also by non-specialists.

A random geometric graph $\mathcal{G}(n,r)$ is obtained by spreading n points uniformly at random in a unit square, and by associating a vertex with each point and an edge with each pair of points at Euclidean distance at most r. Such graphs are extensively used to model wireless ad-hoc networks, and in particular sensor networks. It is well known that, over a critical value of r, the graph is connected with high probability.

In [16] the authors study the robustness of the connectivity of random geometric graphs in the supercritical phase, under deletion of edges. In particular, they show that, for a sufficiently large r, any cut which separates two components of $\Theta(n)$ vertices each contains $\Omega(n^2r3)$ edges with high probability. They also present a simple algorithm that, again with high probability, computes one such cut of size $O(n^2r3)$.

Algorithms for the Web. Wikipedia (www.wikipedia.org) is an online encyclopedia, available in more than 100 languages and comprising over 1 million articles in its En-

glish version. If we consider each Wikipedia article as a node and each hyperlink between articles as an arc we have a Wikigraph, a graph that represents the link structure of Wikipedia. The Wikigraph differs from other Web graphs studied in the literature by the fact that there are timestamps associated with each node. The timestamps indicate the creation and update dates of each page, and this allows us to perform a detailed analysis of the Wikipedia evolution over time. In the first part of [7] the authors characterize this evolution in terms of users, editions and articles; in the second part, they depict the temporal evolution of several topological properties of the Wikigraph. The insights obtained from the Wikigraphs can be applied to large Web graphs from which the temporal data is usually not available.

In [8] the authors show that the empirical distribution of the PageRank values in a large set of Web pages does not follow a power-law except for some particular choices of the damping factor. They argue that for a graph with an in-degree distribution following a power-law with exponent between 2.1 and 2.2, choosing a damping factor around 0.85 for PageRank yields a power-law distribution of its values. They suggest that power-law distributions of PageRank in Web graphs have been observed because the typical damping factor used in practice is between 0.85 and 0.90.

In [3] the authors present a detailed statistical analysis of the characteristics of partial Web graphs obtained by sub-sampling a large collection of Web pages. They show that in general the macroscopic properties of the Web are better represented by a shallow exploration of a large number of sites than by a deep exploration of a limited set of sites. They also describe and quantify the bias induced by the different sampling strategies, and show that it can be significant even if the sample covers a large fraction of the collection.

In [10] the authors describe the WEBSPAM-UK2006 collection, a large set of Web pages that have been manually annotated with labels indicating if the hosts are include Web spam aspects or not. This is the first publicly available Web spam collection that includes page contents and links, and that has been labelled by a large and diverse set of judges.

In [4] the authors present link-based techniques for automating the detection of Web spam, that is, pages using deceptive techniques for obtaining an undeservedly high score in search engines. The problem of Web spam is widespread and difficult to solve, mostly due to the large size of the Web that makes many algorithms infeasible in practice.

The authors perform a statistical analysis of a large collection of Web pages. In particular, they compute statistics of the links in the vicinity of every Web page applying rank propagation and probabilistic counting over the entire Web graph in a scalable way. They build several automatic web spam classifiers using different techniques. This paper presents a study of the performance of each of these classifiers alone, as well as their combined performance.

The techniques proposed only consider the link structure of Web, regardless of page contents. The proposed classifiers can detect about 70%-80% of the spam hosts with a rate of false positives of 2%-7%. This is competitive with the performance state-of-the-art spam classifiers that use content attributes, and orthogonal to their methods.

In [15] the authors present two space bounded algorithms that with probability at least 1 compute a (1 +- -approximation of the number of triangles in an undirected graph

given as a stream of edges. Both algorithms are based on random sampling. The first algorithm proposed does not make any assumption on the order of edges in the stream. It uses space that is inversely related to the ratio between the number of triangles and the number of triples with at least one edge in the induced subgraph, and constant expected update time per edge. Our second algorithm is designed for incidence streams (all edges incident to the same vertex appear consecutively). It uses space that is inversely related to the ratio between the number of triangles and length 2 paths in the graph and expected update time $O(\log |V| \cdot (1 + s \cdot |V|/|E|))$, where s is the space requirement of the algorithm. These results significantly improve over previous work. Since the space complexity depends only on the structure of the input graph and not on the number of nodes, our algorithms scale very well with increasing graph size and so they provide a basic tool to analyze the structure of large graphs. They have many applications, for example, in the discovery of Web communities, the computation of clustering and transitivity coefficient, and dis- covery of frequent patterns in large graphs. The authors implemented both algorithms and evaluated their performance on networks from different application domains. The sizes of the considered graphs varied from about 8, 000 nodes and 40, 000 edges to 135 million nodes and more than 1 billion edges. For both algorithms we run experiments with parameter s = 1, 000, 10, 000, 100, 000, 1, 000, 000 to evaluate running time and approximation guarantee. Both algorithms appear to be time efficient for these sample sizes. The approximation quality of the first algorithm was varying significantly and even for s = 1, 000, 000 there was more than 10% deviation for more than half of the instances. The second algorithm performed much better and even for s = 10, 000 it had an average deviation of less than 6% (taken over all but the largest instance for which we could not compute the number of triangles exactly).

In [21] the authors present an experimental study of the properties of web graphs. They study a large crawl from 2001 of 200M pages and about 1.4 billion edges made available by the WebBase project at Stanford, and synthetic graphs obtained by the large scale simulation of stochastic graph models for the Webgraph. This work required the development and the use of external and semi-external algorithms for computing properties of massive graphs, and for the large scale simulation of stochastic graph models. The authors report their experimental findings on the topological properties of such graphs, describe the algorithmic tools developed within this project and report the experiments on their time performance.

In [22] the authors present an experimental study of the properties of web graphs. We study a large crawl from 2001 of 200M pages and about 1.4 billion edges made available by the WebBase project at Stanford. The authors report their experimental findings on the topological properties of such graphs, such as the number of bipartite cores and the distribution of degree, PageRank values and strongly connected components.

Algorithms for optimization. In computability and in complexity theory, reductions are widely used for mapping sets into sets in order to prove undecidability or hardness results. In the study of the approximate solvability of hard discrete optimization problems, suitable kinds of reductions, called approximation preserving reductions, can also

be used to transfer from one problem to another either positive results (solution techniques) or negative results (non approximability results). In [1] various kinds of approximation preserving reductions are surveyed and their properties discussed. The role of completeness under approximation preserving reductions is also analyzed and its relationship with hardness of approximability is explained.

A natural question in data stream processing is whether we can reduce the space usage at the price of increasing the number of passes over the data. Unfortunately, this seems to be very hard for many graph problems, unless powerful primitives such as sorting are used. And yet, even using sorting, problems such as shortest paths remain difficult. In [4] the authors show that, for any space restriction of s bits, single-source shortest paths in directed graphs with small positive integer edge weights can be solved in $O((nlog^{3/2}n)/\sqrt(s))$ passes. For undirected connectivity, they devise an O((n log n)/s) passes algorithm. Both problems require $\Omega(n/s)$ passes under the restrictions we consider. The proposed algorithms do not use sorting as a primitive and work in the W-Stream model introduced by Aggarwal et al. in FOCS 2004.

In [2] the authors introduce the notion of smoothed competitive analysis of online algorithms. Smoothed analysis has been proposed by Spielman and Teng [STOC 2001] to explain the behaviour of algorithms that work well in practice while performing very poorly from a worst case analysis point of view. They apply this notion to analyze the Multi-Level Feedback (MLF) algorithm to minimize the total flow time on a sequence of jobs released over time when the processing time of a job is only known at time of completion. The initial processing times are integers in the range $[1, 2^K]$. The authors use a partial bit randomization model, where the initial processing times are smoothened by changing the k least significant bits under a quite general class of probability distributions. They show that MLF admits a smoothed competitive ratio of $O((2^k/\sigma)^3 + (2^k/\sigma)^2 2^{K-k})$, where σ denotes the standard deviation of the distribution. In particular, they obtain a competitive ratio of $O(2^{K-k})$ if $\sigma = \Theta(2^k)$. They also prove an $\Omega(2^{K-k})$ lower bound for any deterministic algorithm that is run on processing times smoothened according to the partial bit randomization model. For various other smoothening models, including the additive symmetric smoothening model used by Spielman and Teng, we give a higher lower bound of $\Omega(2^K)$. A direct consequence of our result is also the first average case analysis of MLF. Finally, the authors show a constant expected ratio of the total flow time of MLF to the optimum under several distributions including the uniform distribution.

Game theory. Recently, paradigms and mathematical concepts from game theory have been adopted in the analysis of resource management policies in large networks in order to maintain control over the degradation of network performances caused by the selfishness of users. In this area we have addressed the following problems.

In [6] the authors study budgeted variants of classical cut problems: the Multiway Cut problem, the Multicut problem, and the k-Cut problem, and provide approximation algorithms for these problems. Specifically, for the budgeted multiway cut and the k-cut problems they provide constant factor approximation algorithms. They show that the

budgeted multicut problem is at least as hard to approximate as the sparsest cut problem, and they provide a bi-criteria approximation algorithm for it.

In the multi-commodity rent-or-buy network design problem (MRoB) we are given a network together with a set of k terminal pairs $R = \{(s_1, t_1), \ldots (s_k, t_k)\}$. The goal is to install capacities on the edges of the network so that a prescribed amount of flow f_i can be routed between all terminal pairs s_i and t_i simultaneously. We can either rent capacity on an edge at some cost per unit flow or buy infinite capacity on an edge at some larger fixed cost. The overall objective is to install capacities at a minimum total cost. The version of the stochastic Steiner tree problem (SST) considered here is the Steiner tree problem in the model of two-stage stochastic optimization with recourse. In stage one, there is a known probability distribution on subsets of vertices and we can chose to buy a subset of edges at a given cost. In stage two, a subset of vertices T from the prior known distribution is realized, and additional edges can be bought at a possibly higher cost. The objective is to buy a set of edges in stages one and two so that all vertices in T are connected, and the expected cost is minimized. Gupta et al. gave a randomized scheme for the MRoB problem that was both used subsequently to improve the approximation ratio for this problem, and extended to yield the best approximation algorithm for SST. One building block of this scheme is a good approximation algorithm for the Steiner forest problem. The authors present a simple 5-approximation algorithm for both MRoB and SST, improving on the best previous guarantees of 6.828 and 12.6, and show that this is nearly tight in the following sense: no approximation ratio better than 4.67 can be achieved using the above mentioned randomized scheme in combination with the currently best known Steiner forest approximation algorithms. A key component of our approach are cost shares that are 3-strict for the unmodified primal-dual Steiner forest algorithm.

Experimentation, visualization and applications. In algorithm engineering it is particularly relevant to study and analyze the performance of algorithms not only from the theoretical point of view (through the classical worst case asymptotic analysis) but also by running experiments that allow us to assess the practical behaviour of algorithms on real life data. In this area we have continued our research program by addressing both the experimental study of specific graph algorithms and the design and development of an environment for algorithm visualization.

Leonardo Web is a collection of tools to animate algorithms. Animations can be generated with a visual editor or directly as a trace of an algorithm execution. They can be visualized via a small Java player, available as an applet or as a standalone application; the player supports bidirectional continuous and step-by-step execution. Furthermore, the system allows us to export the animations in several formats, including Macromedia Flash, Microsoft Powerpoint and animated GIF. In [11] the authors discuss the design issues of one of the components of the visual editor of Leonardo Web, called the Builder, that can be used to design an animation from scratch as well as to refine batch-generated ones.

In [12] the authors show how the use of declarative programming can help in the

implementation of algorithm visualization software tools.

Journals

[1] Giorgio Ausiello and Vangelis Th. Paschos. Reductions, completeness and the hardness of approximability. *European Journal of Operations Research*, **172**, pp. 719–739, 2006.

[2] Luca Becchetti, Stefano Leonardi, Alberto Marchetti-Spaccamela, Guido Schaefer and T. Vredeveld. Average case and smoothed competitive analysis of the multi-level feedback algorithm. *Mathematics of Operations Research*, **31**, 2006. A preliminary version appeared in proceedings of the IEEE Symposium on Foundations of Computer Science (FOCS), 2003

[3] Camil Demetrescu and Giuseppe F. Italiano. Fully Dynamic All Pairs Shortest Paths with Real Edge Weights. *Journal of Computer and System Sciences*, **72**(5), pp. 813–837, 2006. Special issue devoted to the best papers selected from the 42th Annual IEEE Symposium on Foundations of Computer Science (FOCS'01).

Conference proceedings

[4] Camil Demetrescu, Irene Finocchi and Andrea Ribichini. Trading off space for passes in graph streaming problems. *Proceedings of the 17th Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'06)*, pp. 714–723, 2006.

[5] Lisa Fleischer, Jochen Koenemann, Stefano Leonardi and Guido Schaefer. Simple Cost Sharing Schemes for Multi-Commodity Rent-or-Buy and Stochastic Steiner Tree. *Proceedings of the 38th ACM Symposium on Theory of Computing Seattle, Washington, USA*, 2006.

[6] Roee Engelberg, Jochen Koenemann, Stefano Leonardi and Joseph (Seffi) Naor. Cut problems in graphs with a budget constraint. *Proceedings of Latin American Theoretical Informatics Symposium, Springer-Verlag,Lecture Notes in Computer Science* , 2006. To appear in the Journal of Discrete Algorithms.

[7] Luciana Buriol, Carlos Castillo, Debora Donato, Stefano Leonardi and Stefano Millozzi. Temporal Evolution of the Wikigraph. *Proceedings of IEEE Web Intelligence*, 2006.

[8] Luca Becchetti and Carlos Castillo. The distribution of PageRank follows a power-law only for particular values of the damping factor. *Proceedings of the 15th international conference on World Wide Web*, pp. 941–942, 2006.

[9] Luca Becchetti, Carlos Castillo, Debora Donato and Adriano Fazzone. A comparison of sampling techniques for Web characterization. *Workshop on Link Analysis (LinkKDD)*, 2006.

[10] Carlos Castillo, Debora Donato, Luca Becchetti, Paolo Boldi, Massimo Santini and Sebastiano Vigna. A Reference Collection for Web Spam. *SIGIR Forum, Vol. 40, No. 2*, 2006.

[11] Vincenzo Bonifaci, Camil Demetrescu, Irene Finocchi and Luigi Laura. Visual Editing of Animated Algorithms: the Leonardo Web Builder. *Proceedings of the 8th International Working Conference on Advanced Visual Interfaces (AVI 2006)*, 2006.

[12] Camil Demetrescu and Irene Finocchi. A Data-driven Graphical Toolkit for Software Visualization. *Proceedings of the 3rd ACM Symposium on Software Visualization (SOFTVIS 2006)*, pp. 57–66, 2006.

[13] Lisa Fleischer, Jochen Konemann, Stefano Leonardi and Guido Schäfer. Simple cost sharing schemes for multicommodity rent-or-buy and stochastic Steiner tree. *Proceedings of the 38th Annual ACM Symposium on Theory of Computing*, 2006.

[14] Luca Becchetti, Carlos Castillo, Debora Donato, Stefano Leonardi and Riccardo Baeza-Yates. Using Rank Propagation and Probabilistic Counting for Link-Based Spam Detection. *Proceedings of the Workshop on Web Mining and Web Usage Analysis (WebKDD), 2006, ACM press*, 2006.

[15] Luciana Buriol, Gereon Frahling, Stefano Leonardi, Alberto Marchetti-Spaccamela and Christian Sohler. Counting Triangles in Data Streams. *Proceedings of Symposium on Principles of Database Systems, PODS, ACM Press*, 2006.

[16] Josep Diaz, Fabrizio Grandoni and Alberto Marchetti-Spaccamela. Balanced Cut Approximation in Random Geometric Graphs. *Proc. ISAAC 2006, Lect. Notes in Computer Sci. Springer Verlag*, 2006.

Ph.D. thesis

[17] Debora Donato. Web Mining and Exploration: Algorithms and Experiments. PhD thesis, University of Rome "La Sapienza", Dipartimento di Informatica e Sistemistica, 2006.

[18] Fabiano Sarracco. Mobile Agents Security: Algorithmic Approaches for Hostile Hosts Detection. PhD thesis, University of Rome "La Sapienza", Dipartimento di Informatica e Sistemistica, 2006.

Submitted papers, technical reports and others

[19] Camil Demetrescu and Giuseppe F. Italiano. Experimental Analysis of Dynamic All Pairs Shortest Path Algorithms. To appear in *ACM Transactions on Algorithms*, 2006. Special issue devoted to selected papers from the 15th Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'04).

[20] Camil Demetrescu and Giuseppe F. Italiano. Dynamic shortest paths and transitive closure: Algorithmic techniques and data structures. To appear in *Journal of Discrete Algorithms*, 2006.

[21] Debora Donato, Luigi Laura, Stefano Leonardi, Ulrich Meyer, Stefano Millozzi and Jop Frederik Sibeyn. Algorithms and Experiments for the Webgraph. To appear in *Journal of Graph Algorithms and Applications (World Scientific Publishing)*, 2006.

[22] Debora Donato, Luigi Laura, Stefano Leonardi and Stefano Millozzi. Modeling the Webgraph: how far we are. To appear in *ACM Transaction on Internet Technology (TOIT)*, 2006.

3.1.2 Artificial Intelligence

The Artificial Intelligence (AI) research group is working on several aspects of AI. For an overview of the state of the art in the field see [5, 6].

The presentation of the research results is arranged along the following lines:

1. The study of computational properties of formalisms, languages, and reasoning tools. These topics are illustrated in the Section "Complexity of Reasoning".

2. The techniques for reasoning under uncertainty, which are based on a probabilistic representation, and used, in particular, to select the best action to execute in a dynamic environment. This is addressed in the Section "Reasoning under Uncertainty".

3. The development of heuristics and suitable formalisms to realize flexible architectures for planning and scheduling. This work is described in the Section on "Constraint-based Architectures for Planning and Scheduling".

4. Computer Vision and State Estimation techniques are very important for assessing the state of a dynamic system, detect relevant situations, monitor and control an environment, etc. These topics are illustrated in the Section "Computer Vision and State Estimation".

5. The techniques for the design and implementation of Cognitive Agents that cooperate in the achievement of a common goal, in multi-robot and multi-agent systems. In particular we focus on applications for emergency operations. These topics are described in the Section "Multi-robot and multi-agent systems".

6. The definition of methods and techniques for reasoning about perception actions, and for the design and the realization of embodied agents (in particular mobile robots) that are able to accomplish complex tasks in real environments. These topics are described in the Section "Cognitive Robotics, learning and perception".

7. The study of declarative modelling languages for constraint problems and the investigation of different and complementary reasoning techniques, that allow the system to reformulate a highly declarative constraint specification into one more efficiently solvable by the given solver, are described in the Section "Constraint modelling and programming".

8. The techniques for the synthesis of physically-plausible animation, which are based on the mechanical laws governing the represented scene, and used, in particular, for entertainment, designing and prototyping. This is addressed in the Section "Computer Graphics".

The international recognition of the achievements in the field of Artificial Intelligence and Knowledge Representation are highlighted by the following honors.

Luigia Carlucci Aiello was a member of the Board of Trustees of IJCAI - the International Joint Conference on Artificial Intelligence, and President of FoLLI, the Association of Logic Language and Information; she is a member of the IJCAI Award Committee, and panel member for the panel PE5 Information and Communication of the ERC, the European research Council. She is in the Editorial Board of several international journals, among them the Artificial Intelligence Journal, and program committees of international conferences.

Fiora Pirri is permanent member of the Cognitive Robotics steering Committee; Daniele Nardi is member of the RoboCup Trustee Board and co-chair of the IEEE TC on "Safety, Security and Rescue Robots"; Marco Schaerf is in the editorial board of the Artificial Intelligence Journal and is the current President of the Italian Artificial Intelligence Association (AI*IA).

The paper [55] by Zaracchi, Fratarcangeli and Iocchi received the best paper award at the RoboCup Simposium 2006.

The book "Action and Interaction in AI Theories and Systems, Essays Dedicated to Luigia Carlucci Aiello", co-edited by Oliviero Stock and Marco Schaerf [23], has been dedicated to Luigia Carlucci Aiello, in appreciation of her leading role in Artificial Intelligence research, and presented to her in the occasion of her birthdate at the ECAI 2006 Conference. The book includes contributions by many members of the research group.

Main projects:

"Post-earthquake emergency: Methods, Techniques and Support Instrumentation" Scientific Cooperation Italy-Japan, Italian Ministry of Foreign Affairs. SIED.

"ROBOtics for the CARE of elderly and disable people (ROBOCARE)" (Italian National Research Council) SIED and ISTC-CNR.

"Implementazione dell'architettura di supervisione del Robot Antartico di Superficie (RAS)" (ENEA).

"Flir-OWS" concerning the fusion between a laser and a FLIR camera for obstacle avoidance purposes. Galileo Avionica (Finmeccanica) ALCOR.

"Stabilizzazione elettronica di immagini" deals with development and application of image stabilization techniques for cameras mounted on aerial vehicles. Galileo Avionica (Finmeccanica) ALCOR.

"Viewfinder"(IST-045541-VIEW-FINDER)[1] has been approved within the European Union FP6 "Advanced Robotics" call. The project consists of 9 European partners. ALCOR.

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

The SPQR team participated at the Robocup 2006 in Bremen in the soccer 4-legged league, Virtual and real Rescue leagues, showing successful implementations of multi-robot coordination techniques. The RoboCare team participated in the RoboCup @Home league and obtained the third place with the prototype robot developed in the RoboCare project. The participation was sponsored by Epistematica.

The ALCOR (AutoAgent Laboratory for Cognitive Robotics) laboratory[2] competed at the Robocup 2006 in Bremen in the Rescue and @Home leagues. The participation was sponsored by the Province of Rome and by Fondazione Cassa di Risparmio. Research at Alcor spans from theoretical aspects of statistical learning applied to shape and texture perception, visual attention and cognitive modelling of artificial agents to security applications.

The group at SIED Laboratory organized the third Rescue Robotics Camp [3], that took place from October 30th to November 3rd.

Before listing the members of the AI group, we dedicate some words to honor the memory of professor Marco CADOLI: a friend, a distinguished scientist, and one of the earliest researchers of the AI group at DIS. He passed away on November 21, 2006, we miss him greatly.

Group members Anna BELARDINELLI, Domenico BLOISI, Marco CADOLI, Daniele CALISI, Andrea CARBONE, Luigia CARLUCCI AIELLO, Amedeo CESTA [CNR], Giuseppe DE GIACOMO, Alessandro FARINELLI, Alberto FINZI, Marco FRATARCANGELI, Simone FRATINI, Giorgio GRISETTI, Luca IOCCHI, Riccardo LEONE, Paolo LIBERATORE, Thomas LUKASIEWICZ, Toni MANCINI, Stefano MARRA, Daniele NARDI, Angelo ODDI [CNR], Marcelo OGLIETTI, Alessio PASCUCCI, Fabio PATRIZI, Federico PECORA, Stefano PELLEGRINI, Fiora PIRRI, Marco PIRRONE, Nicola POLICELLA, Riccardo ROSATI, Giuseppe SARDINA, Francesco SAVELLI, Marco SCHAERF, Francesco SCIALACQUA, Luigi SCOZZAFAVA, Giuseppe SETTEMBRE, Stefano SPARANDII, Gian Diego TIPALDI, Giorgio UGAZIO, Alberto VALERO, Marco ZARATTI, Vittorio Amos ZIPARO

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.

Logical inference is an extraordinarily powerful computational device, and problems in logic are known among computer scientists for their high computational complexity. As an example, the prototypical recursively enumerable, non-recursive problem is to check whether a formula of first-order logic is valid. In other words a reasoner that represents its knowledge by means of a first-order formula and uses a sound and complete procedure for checking the validity of its knowledge has as much computational power as a Turing machine. The reasoner might give up full expressiveness and represent its knowledge in formulae of propositional logic, still using a sound and complete consistency checking procedure. In this case, it is important to recall that checking whether

[2] www.dis.uniroma1.it/ alcor

[3] `http://sied.dis.uniroma1.it/camp`

a formula of propositional logic is consistent is the paradigmatic NP-complete problem, which means that the reasoner faces a problem which probably requires exponential time.

In 2006, 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, the work has been carried out in the context of circuit complexity [2], in satisfiability [14], in default logic [15], in the context of process algebras [18, 36] and in the context of combinatorial games [19]. Moreover, Marco Schaerf has coedited with Oliviero Stock the international book [23] dedicated to Luigia Carlucci Aiello.

Reasoning under uncertainty. The research on reasoning under uncertainty focuses especially on probabilistic reasoning about actions and on uncertainty reasoning for the Semantic Web. In particular, towards game-theoretic extensions of probabilistic reasoning about actions, [43] introduces a combination of partially observable stochastic games with agent programming in Golog, while [41, 42] present an adaptive integration of stochastic games with agent programming in Golog. Towards sophisticated representation and reasoning techniques that allow for uncertainty reasoning in the Semantic Web, [74, 76] present a probabilistic generalization of description logic programs under the answer set and the well-founded semantics, and [31] investigates its application in probabilistic data integration for the Semantic Web, while [46] presents a fuzzy generalization of description logic programs under the answer set semantics. Furthermore, [49, 48, 47] explore the use of variable-strength conditional preferences for matchmaking and ranking objects in description logics, while [77, 78] present in particular probabilistic description logics for the Semantic Web. Finally, [75] presents a new approach to description logic programs under the answer set semantics for the Semantic Web.

Other works explore the computational properties of recent notions of probabilistic entailment as well as the computational properties of basic concepts in structural causal models. More concretely, [73] investigates the computational properties of probabilistic entailment under variable-strength inheritance with overriding, while [11] presents tractable cases for computational problems around Halpern and Pearl's notions of cause and explanation in structure-based causal models.

Constraint-based architectures for planning and scheduling. This line of research synthesizes methods for solving complex planning and scheduling problems. Additional topics are addressed like multi-agent coordination, evaluation methodologies for of interactive intelligent systems and other work strictly connected to the exploitation of the research outcomes in problem solving software architectures.

During the current year, research on scheduling has mainly concerned the problem of schedule execution and monitoring. A specific publication has concerned the proactive approach based on Partial Order Schedules [81]. New research has been developed by using a benchmark generation for project scheduling with temporal uncertainty. The generator has enabled the use of a quantitative experimental setting for comparing the combination of off-line/proactive and on-line/reactive algorithms. A set of interesting

results are described in [53, 52, 83, 65, 64].

A second research topic has been the integration of planning and scheduling. A component-based proposal based on a uniform constraint programming representation has been deeply investigated in [44, 57]. A different perspective that integrates a classical planner and a scheduling core implemented as a separate constraint-based module is described in [17].

In the architectures for scheduling the topic of interaction with real users has been addressed in two directions: producing user-oriented languages for knowledge engineering [16] and evaluating users attitudes in mixed-initiative interaction [37].

Additionally, several of these techniques have been applied in two relevant projects. In ROBOCARE software and robotic agents are integrated to obtain complex functionalities in a domestic environment [20]. In MEXAR2 specific scheduling techniques have been used to solve a daily problem in the MARS EXPRESS mission producing a tool in continuous use at the European Space Agency [9, 34, 35, 66].

Additional work has concerned the problem of distributed coordination in multi-agent planning [80] and a survey on planning and scheduling [8].

Computer vision and state estimation Computer Vision and State Estimation techniques are very important for assessing the state of a dynamic system, detect relevant situations, monitor and control an environment, etc. This paragraph includes our research in computer vision based techniques for state estimation that have been employed in various application fields.

An important task for computer vision based systems and for robotic assistants for elderly people is to detect people and determine their status in the environment. The work in [50] describes a real-time system based on stereo vision that allows for recognizing and tracking human postures. The method uses a 3D human body model, model a matching technique based on a variant of ICP, and Hidden Markov Models to filter observations over time. In application fields, in which object recognition can be implemented relying on colors, it is important to have color segmentation methods that are robust to light variations. In [71] an adaptive color segmentation method is presented. The method is robust to light variations since it implements a transformation of the color distribution of the scene in such a way to adapt to different light conditions.

State estimation includes robot self-localization and simultaneous localization and mapping (SLAM) problems. Analysis of localization methods based on particle filters has been presented in [79], the work has been applied to self-localization task for soccer robots. In [33] we described an interpretation of scan matching as a probability distribution approximation problem and proposed an algorithm that takes advantage of the knowledge of the evolution model by employing a particle approximation to the target distribution. Finally, in [45], we presented two efficient optimizations for Rao-Blackwellized SLAM on grid maps. With our optimizations, we are able to maintain between one and two orders of magnitude more samples and at the same time require less memory and computational resources compared to other state-of-the-art Rao-Blackwellized mapping techniques.

Multi-robot and multi-agent systems Multi-Robot Systems (MRS) and Multi-Agent Systems (MAS) are a common tool for implementing complex systems acting in complex environments, and the ability of the agents to coordinate each other in an effective way is fundamental. In [13] we present an asynchronous distributed algorithm for multi-robot task allocation in a scenario where tasks to be accomplished by the MRS are perceived by the robots during mission execution. Extensions to this approach have been presented in [40, 39] in order to have a minimal bandwidth requirements. Another interesting issue is how to form coalitions among the robots in order to fulfill the common goals. In [38], we present a solution based on an ontology defined with description logics.

General issues concerning the design of robotic systems, possibly involving multi robots are addressed in [10, 21], while in [85, 32] two specific design issues are addressed: plan representation and multi-objective exploration. Moreover, in [12], we present our robot development framework that has been used for realizing many different robotic applications.

Using a simulator is important in robotics application to speed up development and test. A 3D simulator for legged robots is presented in [84], while in [82] we describe the development of a model of our rescue robotic platform and the relative sensors, within the USARSim simulator.

Finally, in [72] we describe research issues and implementation details of a team of autonomous soccer robots: in particular, our approaches to color-based object recognition, self-localization, plan representation and execution, and multi-robot coordination. In [63] we describe an implemented system for elderly assistance based on computer vision and robotics technologies that integrates with a multi-agent coordination mechanism planning and scheduling of activities, people tracking and robot basic functionalities, such as self-localization and mapping and navigation.

Cognitive robotics, learning and perception Research on Cognitive Robotics is aimed at enhance cognitive skills of robotic platforms and has been developed mainly on the topics of Learning, Vision, Exploration and Mapping. Statistical learning techniques have been applied to the implementation of gaze control behaviour and to shape recognition. Human eye movements have been studied by means of a device designed on purpose and hence modelled in a formal way so to infer a plausible gaze behaviour to endow a robot with, as illustrated in [59]. Visual attention, a paramount cognitive skill, has been studied and modeled in [25]. The model aims at discriminating within the amount of information coming from cameras to let a robot fixate meaningful objects and regions. The model of attention was used to quickly extract image portions displaying features related to the searched target [24]. Aspects of vision, still related to attention, concerning spatial representations have been tackled in [1]. In the scope of geometry processing studies on shapes analysis have been conducted in [22], where a composite analysis of shapes based on form and features is presented. In [51] the main part of the analysis focuses on the conditions under which a composite distance can be recovered, by matching the composite shape with models collected in a repository. In [62] we present a task-oriented attentive exploration system designed for an autonomous rover working in rescue scenarios. A

visual-attention process combined with simultaneous localization and mapping guides the robot search using an incremental generation of a global saliency map.

A recent trend in planning with incomplete information is to model the actions of a planning problem as nondeterministic transitions over the belief states of a planner, and to search for a plan that terminates in a desired goal state no matter how these transitions turn out. In [54] we show that this view of planning is fundamentally limited. Specifically, it does not work for iterative planning, where unbounded loops may be necessary. We also show that if in addition to belief states we have also truth states, then we get an account that works properly even for iterative plans.

In [68] we consider the problem of synthesizing a fully controllable target behavior from a set of available partially controllable behaviors that are to execute within a shared partially predictable, but fully observable, environment. We formally define the problem within a general framework in which behaviors are represented as (finite) nondeterministic finite transition systems, characterize its computational complexity, propose a solution by appealing to satisfiability in Propositional Dynamic Logic, which is indeed optimal with respect to computational complexity.

Constraint modelling and programming It is well known that declarative programming, and more specifically constraint programming, is becoming very attractive to solve different classes of problems, one of the main advantages of the approach being the fast prototyping and the high declarativeness exhibited by the problem models (also called "specifications"). Although current systems for constraint solving allow the programmer to model her problem in a highly declarative way, supporting a neat separation of the specification from its instances, it is indeed well-known that such a model is often not performant, and much effort is required by the programmer in order to reformulate it to speed-up the solving process.

Research carried out at DIS aimed at attacking this gap, by focussing on different and complementary aspects:

- Investigate reasoning techniques that could be used to automatically preprocess the constraint model given by the programmer into an equivalent one, more efficiently evaluable by solvers of various classes.

  In particular, in [3] it is shown how some of the constraints of a specification can be ignored in a first step, and then efficiently reinforced (i.e., without performing additional search, the so-called "safe delay" constraints), and a sufficient semantic criterion on the specification is provided, that can be used in order to recognize such constraints.

  Also, in [30], the notion of problem separability is investigated, in particular the separability of subproblems in Benders Decompositions. We provide a semantical definition of Benders Decomposition and characterize it from both the logical and the computational viewpoints, showing the undecidability of the problem of checking whether a selection of input data for a problem corresponds to a separation.

Finally, in [60, 30] it is shown how several forms of reasoning needed to discover properties of constraint models amenable to be optimized could be effectively and often efficiently performed by automated tools, despite the undecidability of the general problem. This step is fundamental in order to provide, in the long-term, constraint programming systems that are effective to optimize structural properties of the problems and to deal with highly declarative specifications.

- Experimentally evaluate [29, 28, 27, 61] the state-of-the-art in complementary technologies for solving constraint problems (e.g., backtracking-based search, local search, SAT, ASP) and the impact that various reformulation techniques (several of them developed at DIS in the previous years) have in all of them. This is a fundamental step in order to assess which reformulation techniques are promising for the different solving technologies.

- Provide highly declarative and simple-to-use languages with well-defined computational properties for constraint modelling and programming [4] that may be able to diffuse the constraint programming paradigm in the industrial environment.

Finally, work on other areas have been carried out during 2006. In particular, in [26] the *iAgree* system is described, that allows partially collaborative distributed agents to perform negotiations in order to achieve mutual satisfactory agreements, when privacy of information is an issue, and no central authority could be used. Negotiation is performed by exchanging proposals and by performing sophisticated forms of reasoning on the remote agent's offers. The system implements a theoretical framework previously developed at DIS, but extends it in order to improve the flexibility of the approach. In particular, each agent continuously evaluates the behavior of the remote peer in order to perform the best kind of reasoning possible, with the goal of minimizing the number of iterations. A survey of the use of logics in AI is given in [7].

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

During 2006, we developed a stable and robust robotic simulator [55] useful in developing robotics applications, both for rapid prototyping of behaviors, scenarios, and also for debugging purposes of many high-level tasks. We also carried on the research on the automatic animation of virtual humans, in particular talking heads driven be facial gestures [69] or by cloning existing facial animation [70], and physically-based skeletons able to find the correct movements in order to reach a predefined goal [67].

Journals

[1] F. Belardinelli, and A. Pirri. A biologically plausible robot attention model, based on space and time. In *Cognitive Processing*, pages 11–14. Springer, 2006.

[2] M. Cadoli, F. M. Donini, P. Liberatore, and M. Schaerf. k-approximating circuits. *IEEE Transactions on Computers*, 55(7):913–917, 2006.

[3] M. Cadoli and T. Mancini. Automated reformulation of specifications by safe delay of constraints. *Artificial Intellelligence Journal*, 170(8–9):779–801, 2006.

[4] M. Cadoli and T. Mancini. Combining Relational Algebra, SQL, Constraint Modelling, and local search. *Theory and Practice of Logic Programming*, 7(1):1–29, 2006.

[5] L. Carlucci Aiello. IA significa lanciare sfide e rincorrerle. *Media Duemila*, XXIV 6:36–39, 2006.

[6] L. Carlucci Aiello. Introduction to the special issue for the 50th anniversary of AI. *Intelligenza Artificiale*, III 1/2:3–6, 2006.

[7] L. Carlucci Aiello, E. Giunchiglia, and L. Serafini. Logics for artificial intelligence. *Intelligenza Artificiale*, III 1/2:7–13, 2006.

[8] A. Cesta and A. Milani. Planning and Scheduling. *Intelligenza Artificiale*, 3(1–2):35–41, 2006.

[9] G. Cesta, A. Cortellessa, S. Fratini, A. Oddi, and N. Policella. MEXAR2 Support to Space Mission Planners. *ERCIM News*, 65:14–15, 2006.

[10] A. Chella, L. Iocchi, I. Macaluso, and D. Nardi. Artificial intelligence and robotics. *Intelligenza Artificiale*, 3(1-2):84–90, 2006.

[11] T. Eiter and T. Lukasiewicz. Causes and explanations in the structural-model approach: Tractable cases. *Artificial Intelligence Journal*, 170(6–7):542–580, May 2006.

[12] A. Farinelli, G. Grisetti, and L. Iocchi. Design and implementation of modular software for programming mobile robots. *International Journal of Advanced Robotic Systems*, 3(1):37–42, March 2006. ISSN 1729-8806.

[13] A. Farinelli, L. Iocchi, D. Nardi, and V. A. Ziparo. Assignment of dynamically perceived tasks by token passing in multi-robot systems. *Proceedings of the IEEE, Special issue on Multi-Robot Systems*, 94(7):1271–1288, 2006.

[14] P. Liberatore. Complexity results on DPLL and resolution. *ACM Transactions on Computational Logic*, 7(1):84–107, 2006.

[15] P. Liberatore. On the complexity of extension checking in default logic. *Information Processing Letters*, 98(2):61–65, 2006.

[16] F. Pecora, R. Rasconi, G. Cortellessa, and A. Cesta. User-Oriented Problem Abstractions in Scheduling, Customization and Reuse in Scheduling Software Architectures. *Innovations in Systems and Software Engineering*, 2(1–2):1–16, 2006.

[17] M. D. Rodriguez-Moreno, A. Oddi, D. Borrajo, and A. Cesta. IPSS: A Hybrid Approach to Planning and Scheduling Integration. *IEEE Transactions on Knowledge and Data Engineering*, 18(12):1681–1695, December 2006.

[18] G. Salaün, L. Bordeaux, and M. Schaerf. Describing and reasoning on web services using process algebra. *International Journal of Business Process Integration and Management*, 1(2):116–128, 2006.

Articles in books

[19] M. Cadoli and M. Schaerf. Partial Solutions with Unique Completion. In O. Stock and M. Schaerf, editors, *Reasoning, Action and Interaction in AI Theories and Systems. Essays Dedicated to Luigia Carlucci Aiello*, volume LNCS 4155, pages 101–115. Springer, Germany, 2006.

[20] A. Cesta and F. Pecora. Integrating Intelligent Systems for Elder Care in ROBOCARE. In W. C. Mann and A. Helal, editors, *Promoting Independence for Older Persons with Disabilities*, pages 65–73. IOS Press, 2006.

[21] D. Nardi and L. Iocchi. Artificial Intelligence in RoboCup. In O. Stock and M. Schaerf, editors, *Reasoning, Action and Interaction in AI Theories and Systems. Essays Dedicated to Luigia Carlucci Aiello*, volume LNCS 4155, pages 193–211. Springer, Germany, 2006.

[22] F. Pirri. About implicit and explicit shape representation. In O. Stock and M. Schaerf, editors, *Reasoning, Action and Interaction in AI theories and systems. Essays Dedicated to Luigia Carlucci Aiello*, volume LNCS 4155, pages 141–158. Springer, Germany, 2006.

Book

[23] O. Stock and M. Schaerf (Editors). *Reasoning, Action and Interaction in AI Theories and Systems, Essays Dedicated to Luigia Carlucci Aiello*, volume LNCS 4155. Springer, Germany, 2006.

Conference proceedings

[24] A. Belardinelli, F. Pirri, and A. Carbone. Robot task-driven attention. In *Proc. International Symposium on Practical Cognitive Agents & Robots (PCAR 06)*, 2006.

[25] F. Belardinelli, F. Pirri, and A. Carbone. Spatial discrimination in task-driven attention. In *Proc. 15th IEEE International Symposium on Robot and Human Interactive Communication*, volume TH8907, pages 321–327, 2006.

[26] M. Cadoli, G. Chella, and T. Mancini. iAgree: a system for proposal-based negotiation among intelligent agents. In *Proc. of ECAI 2006*, Riva del Garda, Trento, Italy, 2006. IOS Press, Amsterdam. System demonstration.

[27] M. Cadoli, T. Mancini, D. Micaletto, and F. Patrizi. Evaluating ASP and commercial solvers on the CSPLib – Preliminary report. In Michael Fink, Hans Tompits, and Stefan Woltran, editors, *Proc. of WLP 2006*, volume 1843-06-02 of *INFSYS Research Report*, pages 54–63, Vienna, Austria, 2006. Technische Universität Vienna, Austria.

[28] M. Cadoli, T. Mancini, D. Micaletto, and F. Patrizi. Evaluating ASP and commercial solvers on the CSPLib. In *Proc. of ECAI 2006*, pages 68–72, Riva del Garda, Trento, Italy, 2006. IOS Press, Amsterdam.

[29] M. Cadoli, T. Mancini, and F. Patrizi. SAT as an effective solving technology for constraint problems. In *Proc. of ISMIS 2006*, volume 4203 of *LNCS*, pages 540–549, Bari, Italy, 2006. Springer.

[30] M. Cadoli and F. Patrizi. On the separability of subproblems in benders decompositions. In J. Christopher Beck and Barbara M. Smith, editors, *CPAIOR*, volume 3990 of *Lecture Notes in Computer Science*, pages 74–88. Springer, 2006.

[31] A. Calì and T. Lukasiewicz. An approach to probabilistic data integration for the Semantic Web. In *Proceedings of the ISWC-2006 Workshop on Uncertainty Reasoning for the Semantic Web (URSW-2006)*, volume 218 of *CEUR Workshop Proceedings*, Athens, GA, USA, November 2006. CEUR-WS.org.

[32] D. Calisi, A. Farinelli, L. Iocchi, D. Nardi, and F. Pucci. Multi-objective autonomous exploration in a rescue environment. In *Proc. of IEEE International Workshop on Safety, Security and Rescue Robotics (SSRR)*, 2006.

[33] A. Censi. Scan matching in a probabilistic framework. In *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA'06)*, pages 2291–2296, Orlando, Florida, 2006.

[34] G. Cesta, A. Cortellessa, S. Fratini, A. Oddi, and N. Policella. From Demo to Practice: the MEXAR Path to Space Operations. In M. Ali and R. Dapoigny, editors, *IEA/AIE 2006*, number 4031 in Lecture Notes in Artificial Intelligence, pages 421–431. Springer, 2006.

[35] G. Cesta, A. Cortellessa, S. Fratini, A. Oddi, and N. Policella. Software Companion. The MEXAR2 Support to Space Mission Planners. In *Proceedings of the 17th European Conference on Artificial Intelligence, ECAI-06*, 2006.

[36] A. Chirichiello and G. Salaün. Formal development of web services. In *Proceeding of the 4th International Workshop on AI for Service Composition*, pages 36–43, Riva del Garda (TN), Italy, Aug 28 - Sept 1, 2006.

[37] G. Cortellessa and A. Cesta. Evaluating Mixed-Initiative Systems: An Experimental Approach. In *Proceedings of the 16th International Conference on Automated Planning & Scheduling, ICAPS-06*, 2006.

[38] L. Fanelli, A. Farinelli, L. Iocchi, D. Nardi, and G.P. Settembre. Ontology-based coalition formation in heterogeneous mrs. In *Proceedings of International Symposium on Practical Cognitive Agents and Robots*, pages 105–116, Perth, Australia, 2006.

[39] A. Farinelli, L. Iocchi, and Nardi D. Point to point vs broadcast communication for conflict resolution. In *Proc. of Agent Technology for Disaster Management ATDM06 (AAMAS Workshop)*, pages 32–40, Hakodate, Japan, 2006.

[40] A. Farinelli, L. Iocchi, and D. Nardi. Conflict resolution with minimal communication bandwidth. In *Proc. of IEEE Workshop on Distributed Intelligent Systems*, pages 7–12, Los Alamitos CA, USA, 2006. ISBN: 0-7695-2589-X.

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

[42] A. Finzi and T. Lukasiewicz. Adaptive multi-agent programming in GTGolog. In *Proceedings of the 17th biennial European Conference on Artificial Intelligence (ECAI-2006)*, pages 753–754, Riva del Garda, Italy, August/September 2006. IOS Press.

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

[44] S. Fratini and A. Cesta. A Planning and Scheduling Tool to Automate and Support Mission Planning. In *In Proceedings of the 9th International Conference on Space Operations, SpaceOps 06*, 2006.

[45] G. Grisetti, G. D. Tipaldi, C. Stachniss, W. Burgard, and D. Nardi. Speeding up rao blackwellized slam. In *Proc. of the IEEE Int. Conf. on Robotics And Automation (ICRA)*, pages 442–447, Orlando, FL, USA, 2006.

[46] T. Lukasiewicz. Fuzzy description logic programs under the answer set semantics for the Semantic Web. In *Proceedings of the 2nd International Conference on Rules and Rule Markup Languages for the Semantic Web (RuleML-2006)*, pages 89–96, Athens, GA, USA, November 2006. IEEE Computer Society.

[47] T. Lukasiewicz and J. Schellhase. Preferences, links, and probabilities for ranking objects in ontologies. In *Proceedings of the ISWC-2006 Workshop on Uncertainty Reasoning for the Semantic Web (URSW-2006)*, volume 218 of *CEUR Workshop Proceedings*, Athens, GA, USA, November 2006. CEUR-WS.org.

[48] T. Lukasiewicz and J. Schellhase. Variable-strength conditional preferences for matchmaking in description logics. In *Proceedings of the 10th International Conference on Principles of Knowledge Representation and Reasoning (KR-2006)*, pages 164–174, Lake District, UK, June 2006. AAAI Press.

[49] T. Lukasiewicz and J. Schellhase. Variable-strength conditional preferences for ranking objects in ontologies. In *Proceedings of the 3rd European Semantic Web Conference (ESWC-2006)*, volume 4011 of *Lecture Notes in Computer Science*, pages 288–302, Budva, Montenegro, June 2006. Springer.

[50] S. Pellegrini and L. Iocchi. Human posture tracking and classification through stereo vision. In *Proc. of Int. Conf. on Computer Vision Theory and Applications (VISAPP)*, pages 261–269, 2006. ISBN: 972-8865-40-6.

[51] F. Pirri and A. Pascucci. Implicit and explicit analysis of shapes. In *ICVW 2006 - Second International Cognitive Vision Workshop*, 2006.

[52] R. Rasconi, N. Policella, and A. Cesta. Integrating Off-line and On-line Schedulers. In *Proceedings of the 17th European Conference on Artificial Intelligence, ECAI-06*, 2006.

[53] R. Rasconi, N. Policella, and A. Cesta. SEaM: Analyzing Schedule Executability through Simulation. In M. Ali and R. Dapoigny, editors, *IEA/AIE 2006*, number 4031 in Lecture Notes in Artificial Intelligence, pages 410–420. Springer, 2006.

[54] S. Sardiña, G. De Giacomo, Y. Lespérance, and H. J. Levesque. On the limits of planning over belief states under strict uncertainty. In *KR-2006*, pages 463–471, 2006.

[55] M. Zaratti, M. Fratarcangeli, and L. Iocchi. A 3d simulator of multiple legged robots based on usarsim. In *Proceedings of Robocup Symposium*, Bremen, Germany, June 2006.

Ph.D. thesis

[56] S. Bahadori. *Human Body Detection in Search and Rescue Missions*. PhD thesis, University of Rome "La Sapienza", Dipartimento di Informatica e Sistemistica, 2006.

[57] S. Fratini. *Integrating Planning and Scheduling in a Component-Based Perspective: from Theory to Practice*. PhD thesis, Computer Engineering, University of Rome "La Sapienza", March 2006.

[58] G. Grisetti. *Scaling Rao-Blackwllized Simultaneous Localization and Mapping to Large Envronments*. PhD thesis, University of Rome "La Sapienza", Dipartimento di Informatica e Sistemistica, 2006.

Submitted papers, technical reports and others

[59] A. Belardinelli, F. Pirri, and A. Carbone. Bottom-up gaze shifts and fixations learning, by imitation. *IEEE Transactions on Systems, Man, and Cybernetics, Part B*, page to appear, 2007.

[60] M. Cadoli and T. Mancini. Using a theorem prover for reasoning on constraint problems. *Applied Artificial Intelligence*. Special issue on "Best papers from AI*IA 2005". To appear.

[61] M. Cadoli, T. Mancini, D. Micaletto, and F. Patrizi. Evaluating ASP and commercial solvers on the CSPLib. In Marco Gavanelli and T. Mancini, editors, *Atti della Giornata di Lavoro: Analisi sperimentale e benchmark di algoritmi per l'Intelligenza Artificiale*, Università di Udine, Italy, June 23 2006.

[62] A. Carbone, D. Ciacelli, A. Finzi, and F. Pirri. Autonomous attentive exploration in search and rescue scenarios. In *4th International Workshop on Attention in Cognitive Systems*, 2007.

[63] A. Cesta, F. Pecora, R. Rasconi, L. Iocchi, R. Leone, and D. Nardi. Lucia: a cognitive robot in an intelligent environment. In *RSS Workshop on Socially Assistive Robotics*, 2006.

[64] A. Cesta, N. Policella, and R. Rasconi. Coping with Change in Scheduling: Toward Proactive and Reactive Integration. *Intelligenza Artificiale*, 2006. to appear.

[65] A. Cesta, N. Policella, and R. Rasconi. Integrating Off-line and On-line Scheduling Approaches. In *Proceedings of Workshop on on Experimental Analysis and Benchmarks for AI Algorithms AI*IA-RCRA Working Group*, 2006.

[66] G. Cesta, A. Cortellessa, S. Fratini, A. Oddi, and N. Policella. MEXAR2 - An Operational Tool for Continuous Support to Mission Planning. In *Proceedings of the 5th International Workshop on Planning and Scheduling for Space, IWPSS-06*, 2006.

[67] M. Conventi and M. Schaerf. Physically-based animations of 3d biped characters through genetic algorithms. In *Submitted to 3IA'2007 - 10th International Conference on Computer Graphics and Artificial Intelligence*, Athens, Greece, May 2007.

[68] G. De Giacomo and S. Sardiñ. Automatic synthesis of new behaviors from a library of available behaviors. In *International Joint Conferences on Artificial Intelligence (IJCAI)*, pages 1866–1871, 2007.

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

[70] M. Fratarcangeli, Schaerf M., and R. Forchheimer. Facial motion cloning with radial basis functions in `mpeg-4 fba`. *Graphical Models*, March 2007. To be published.

[71] L. Iocchi. Robust color segmentation through adaptive color distribution transformation. In *Proc. of RoboCup Symposium (CD-ROM Proceedings)*, 2006.

[72] L. Iocchi, D. Nardi, L. Marchetti, and V. A. Ziparo. S.P.Q.R. Legged Team Description Paper. In *Proc. of RoboCup 2006 (CD-ROM Proceedings)*, 2006.

[73] T. Lukasiewicz. Nonmonotonic probabilistic logics under variable-strength inheritance with overriding: Complexity, algorithms, and implementation. *International Journal of Approximate Reasoning*, 2006 (in press).

[74] T. Lukasiewicz. Probabilistic description logic programs. *International Journal of Approximate Reasoning*, 2006 (in press).

[75] T. Lukasiewicz. A novel combination of answer set programming with description logics for the Semantic Web. Technical Report INFSYS RR-1843-06-08, Institut für Informationssysteme, Technische Universität Wien, December 2006.

[76] T. Lukasiewicz. Probabilistic description logic programs. Technical Report INFSYS RR-1843-06-04, Institut für Informationssysteme, Technische Universität Wien, June 2006.

[77] T. Lukasiewicz. Probabilistic description logics for the Semantic Web. Technical Report INFSYS RR-1843-06-05, Institut für Informationssysteme, Technische Universität Wien, July 2006.

[78] T. Lukasiewicz and U. Straccia. An overview of uncertainty and vagueness in description logics for the Semantic Web. Technical Report INFSYS RR-1843-06-07, Institut für Informationssysteme, Technische Universität Wien, October 2006.

[79] L. Marchetti, G. Grisetti, and L. Iocchi. A comparative analysis of particle filter based localization methods. In *Proc.of RoboCup Symposium (CD-ROM Proceedings)*, 2006.

[80] F. Pecora, P. Jay Modi, and P. Scerri. Reasoning About and Dynamically Posting n-ary Constraints in ADOPT. In *Proceedings of 7th Int. Workshop on Distributed Constraint Reasoning at AAMAS*, 2006.

[81] N. Policella, A. Cesta, A. Oddi, and Stephen F. Smith. From Precedence Constraint Posting to Partial Order Schedules: A CSP Approach to Robust Scheduling. *AI Communications*, 2006. to appear.

[82] G. Polverari, D. Calisi, A. Farinelli, and D. Nardi. Development of an autonomous rescue robot within the USARSim 3d virtual environment. In *Proc. of RoboCup Symposium (CD-ROM Proceedings)*, 2006.

[83] R. Rasconi, N. Policella, and A. Cesta. Fix the Schedule or Solve Again? Comparing Constraint-Based Approaches to Schedule Execution. In *Proceedings of the ICAPS Workshop on Constraint Satisfaction Techniques for Planning and Scheduling Problems*, 2006.

[84] M. Zaratti, M. Fratarcangeli, and L. Iocchi. A 3d simulator of multiple legged robots based on usarsim. In *Proc. of RoboCup Symposium (CD-ROM Proceedings)*, 2006.

[85] V. A. Ziparo and L. Iocchi. Petri net plans. In *Proc. of Fourth International Workshop on Modelling of Objects, Components, and Agents (MOCA'06)*, Turku, Finland, 2006.

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 Networks. In particular we concentrate on:
1. Communications in mobile ad-hoc networks;
2. Sensor networks
3. Link analysis of WWW pages;

The achievements of the CN group are widely recognized. Members of the CN group are involved in the Program and Steering Committees of reknown International Conferences. We refer to the sections on Algorithm Engineering and Distributed Systems of this report for a thorougly presentation.

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).

The CN group is presently involved in the following research projects: ALENIA Spazio "Wideband Wireless Local Area Network" (WWLAN); EU Contract 001907 "Dynamically Evolving Large Scale Information Sytems" (DELIS); EU/IST Integrated Project IP-FP6-015964 AEOLUS, "Algorithmic Principles for Building Efficient Overlay Computers"; MIUR National Project "Algorithms for the Next Generation Internet and Web: Methodologies, Design and Application" (ALGO-NEXT); MIUR Firb international Italian-Israelian cooperation RBIN047MH9 project, started in September 2006; "Resilience for Survivability in IST" ReSIST (EU-IST); MIUR "Infrastrutture Software per Reti Ad-hoc Orientate ad Ambienti Difficili" (IS-MANET).

Faculty members Roberto BALDONI, Luca BECCHETTI, Roberto BERALDI, Stefano LEONARDI, Alberto MARCHETTI-SPACCAMELA.
Post-docs Carlos CASTILLO, Kleoni IOANNIDO, Andrea VITALETTI.
PhD students Vincenzo BONIFACI, Debora DONATO, Adnan NOOR MIAN, Leonardo QUERZONI.

Mobile ad hoc networks Point-to-point transmissions represent a fundamental primitive in any communication network. Despite many proposals have appeared in the literature, providing an efficient implementation of such an abstraction in Mobile Ad Hoc Networks (MANETs) still remains an open issue. In [1] we proposed a probabilistic protocol for unicast packet delivery in a MANET. Unlike the classical routing protocols, in our proposal packet forwarding is not driven by a previously computed path. Rather, the nodes of the network exploit a set of routing meta-information (called hints) to discover a path to the destination on-the-fly.

This ensures robustness with respect to topological changes, while requiring a very low overhead. A node gathers hints from the nodes located within a small number of hops (called the protocol's lookahead) from itself. As showed through simulations, very good performance can be obtained with small lookahead. The main statistical properties of hints have been investigated through an analytical model, which is also reported in the paper.

In [8] we presented a novel probabilistic protocol for path discovery in Mobile Ad Hoc Networks (MANETs). The protocol implements what we call a polarized gossiping algorithm. While in the classical gossip algorithm each node forwards a message with the same probability, our proposal is characterized by a variable gossiping probability, which is high enough only for sustaining the spreading process towards the destination. The gossiping probability of a node is determined by the difference between its proximity to the destination and the proximity to the destination of the node from which the message was received. Differently from other proposals no external location service support, e.g. via GPS, is required. Rather, the proximity is estimated from the network using periodic beacons for determining the time elapsed since a node met the destination and the dwell time of a node with the destination. This information is then exploited by nodes to modulate their gossiping probability. The paper reports a mathematical model for the analysis of the algorithm along with an extensive simulation study of its implementation, which shows the suitability of the proposed solution.

Service discovery in mobile ad hoc networks (MANETs) is a challenging issue. The nodes in a MANETs offer spontaneous and variable connectivity. Also the proximity of a given service as well as the kind and the number of services vary unpredictably with time. Tradi- tional directory based architectural solutions can hardly cope with such a dynamic environment while a directory-less approach has to resort to network-wide searches. Some solutions integrate a Service Discovery Pro- tocol (SDP) with the routing protocol. There has been lot of work on the problem of service discovery by leveraging on the random walk based search in wired peer-to-peer networks. These works present interesting results that can be useful for MANETs and can be good candidates for SDP, as these methods require fewer resources as compared to SDPs using some sort of ooding. In [2] we have identified some of the open problems in service discovery in MANETs that use random walk.

Sensor networks In the last few years, wireless sensor networks have enjoyed an extremely high popularity in the research community. Contributions span from data dissemination algorithms to channel access techniques as well as interest dissemination protocols and neighbor estimation algorithms. We note that previous work mainly focuses only on some aspects of the whole sensor system, by either addressing the forward (interest dissemination) or backward (data gathering) communication phases, but without considering them together. The paper [7] presents an integrated approach for data delivery and interest dissemination in wireless sensor networks. The proposed algorithms are designed to work under very low duty cycle operations and are jointly optimized for improved efficiency. Routing towards the sink is achieved by exploiting hop count coor-

dinates which are proactively distributed during the interest dissemination phase. Node densities are locally and dynamically estimated at each node and exploited at the MAC layer by means of a cost based probabilistic scheme. Routing is implemented during channel access according to a cross-layer approach, where nodes with low costs (residual energies, link conditions, queue lengths) are elected with higher probability as the next hop. The proposed solution is a step towards the definition of complete, self-adapting and autonomous sensor network systems and the philosophy of this approach can prove useful to implement adaptive, self-adjusting strategies for connectivity maintenance in general wireless networks.

A particular feature of sensor networks is that they are highly energy constrained due to their use of batteries. [5] investigates data aggregation as a possible way to save energy consumption: nodes may delay data in order to aggregate them into a single packet before forwarding them towards some central node (or nodes). Latency constraints restrict the delay allowed for data arriving at the central node. This model gives rise to interesting and challenging algorithmic problems. In [5] the authors prove that the off-line version of the sensor problem is strongly NP-hard and provide a 2-approximation algorithm. Siunce almost all real life sensor networks are managed in an on-line fashion distributed on-line models have been also analysed both if the nodes are synchronized and non-synchronized and apply competitive analysis into the quality of algorithms.

In [6] the author study the Wireless Gathering Problem, that requires to find a schedule for data gathering in a wireless static network. The problem is to gather a set of messages from the nodes in the network at which they originate to a central node, representing a more powerful base station. The objective is to minimize the time to gather all messages. The sending pattern or schedule should avoid interference of radio signals, which distinguishes the problem from wired networks. We have studied the Wireless Gathering Problem from a combinatorial optimization point of view in a centralized setting. This problem is known to be NP-hard when messages have no release time. We consider the more general case in which messages may be released over time. For this problem we present a polynomial-time on-line algorithm which gives a 4-approximation. We also show that within the class of shortest path following algorithms no algorithm can have approximation ratio better than 4. We also formulate some challenging open problems concerning complexity and approximability for variations of the problem.

Link analysis of the WWW In [3] the authors present a detailed statistical analysis of the characteristics of partial Web graphs obtained by sub-sampling a large collection of Web pages. They show that in general the macroscopic properties of the Web are better represented by a shallow exploration of a large number of sites than by a deep exploration of a limited set of sites. They also describe and quantify the bias induced by the different sampling strategies, and show that it can be significant even if the sample covers a large fraction of the collection.

In [4] the authors present link-based techniques for automating the detection of Web spam, that is, pages using deceptive techniques for obtaining an undeservedly high score in search engines. The problem of Web spam is widespread and difficult to solve, mostly

due to the large size of the Web that makes many algorithms infeasible in practice.

The authors perform a statistical analysis of a large collection of Web pages. In particular, they compute statistics of the links in the vicinity of every Web page applying rank propagation and probabilistic counting over the entire Web graph in a scalable way. They build several automatic web spam classifiers using different techniques. This paper presents a study of the performance of each of these classifiers alone, as well as their combined performance.

The techniques proposed only consider the link structure of Web, regardless of page contents. The classifiers proposed can detect about 70%-80% of the spam hosts with a rate of false positives of 2%-7%. This is competitive with the performance state-of-the-art spam classifiers that use content attributes, and orthogonal to their methods.

Journals

[1] R. Beraldi, L.Querzoni, R. Baldoni. A Hint Based Probabilistic Protocol for Unicast Communications in MANETs. *Elsevier Ad Hoc Networks*, volume 4, 5, 2006.

Conference proceedings

[2] Adnan Noor Mian, Roberto Beraldi, and Roberto Baldoni. Identifying Open Problems in Random Walk based Service Discovery in Mobile Ad hoc Networks. *VI International Workshop on Innovative Internet Community Systems 2006*, June 26-28, 2006 Neuchtel, Switzerland.

[3] L. Becchetti, C. Castillo, D. Donato and A. Fazzone. A comparison of sampling techniques for Web characterization. *Workshop on Link Analysis (LinkKDD)*, 2006.

[4] L. Becchetti, C. Castillo, D. Donato, S. Leonardi and R. Baeza-Yates. Using Rank Propagation and Probabilistic Counting for Link-Based Spam Detection. *Proceedings of the Workshop on Web Mining and Web Usage Analysis (WebKDD), 2006, ACM press*, 2006.

[5] L. Becchetti, P. Korteweg, A. Marchetti-Spaccamela, M. Skutella, L. Stougie and A. Vitaletti. Latency Constrained Aggregation in Sensor Networks. *Proceedings of the European Symposium on Algorithms (ESA)*, 2006.

[6] V. Bonifaci, P. Korteweg, A. Marchetti-Spaccamela and L. Stougie An approximation algorithm for the wireless gathering problem. L. Arge, R. Freivals (eds.), Proc. 10th Scandinavian Workshop on Algorithm Theory, Lecture Notes in Computer Science 4059, Springer, 2006.

[7] M. Mastrogiovanni, C. Petrioli, M. Rossi, A. Vitaletti and M. Zorzi. Integrated data delivery and interest dissemination techniques for wireless sensor networks. *49th annual IEEE Global Telecommunications Conference*, 2006.

Submitted papers, technical reports and others

[8] R. Beraldi. The Polarized Gossip Protocol for Path Discovery in MANETs. *Elsevier Ad Hoc Networks* (to appear).

3.1.4 Data and Knowledge Bases

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

- Description Logics, i.e., the specification of formal languages for representing structured knowledge in different contexts, and for reasoning over such knowledge with suitable computational properties.
- Data Integration, with special focus on data integration under integrity constraints, data inconsistency, and preference-driven data integration.
- View-based Query Processing, and in particular view-based query answering, rewriting and containment.
- Information Visualization, with special focus on theoretical and application-oriented aspects of visual formalisms for data-bases and database design, on Visual Query Languages and Interfaces, Visual Data Mining, and clutter reduction.
- Mobile Information Access, with particular interest on designing applications for multiple user interfaces, and studying the impact of technologies, especially mobile, on digital libraries.
- User interfaces to digital libraries, i.e., the study of user interface design and information visualization in digital libraries.
- E-learning, and in particular the study of how to make accessible information contents.
- Data Quality, with focus on both defining and measuring the quality of data and on the issue of improving the quality of data through data cleaning techniques, specifically record linkage and object identification techniques.

Members of the group participated in international activities about the topics mentioned above. In particular, Maurizio Lenzerini has been co-chair of the International Conference on Ontologies, DataBases, and Applications of Semantics (ODBASE 2006) [21].

The group is presently involved in several research projects, including the following: Progetto MIUR (FIRB) MAIS - Multichannel Adaptive Information Systems; Progetto CNR VICE; Progetto CNR-FISR “Le nuove tecniche di governo e l’innovazione tecnologica nella formazione e attuazione delle politiche pubbliche”; IST NoE DELOS (G038-507618); project HYPER, funded by IBM through a Shared University Research

(SUR) Award grant; MIUR FIRB 2005 project "Tecnologie Orientate alla Conoscenza per Aggregazioni di Imprese in Internet" (TOCAI.IT).

Group members: Carola AIELLO, Enrico BERTINI, Tiziana CATARCI, Giuseppe DE GIACOMO, Loredana DE GIOVANNI, Stephen KIMANI, Domenico LEMBO, Maurizio LENZERINI, Diego MILANO, Valeria MIRABELLA, Antonella POGGI, Riccardo ROSATI, Marco RUZZI, Silvio SALZA, Giuseppe SANTUCCI, Monica SCANNAPIECO.

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

Description logics. The goal of the research in Description Logics (DLs) is to study the foundations of class-based knowledge representation formalisms, with regards to both the expressive power and the computational properties of the associated reasoning techniques. The members of the Data and Knowledge Bases group interested in research in DLs have produced a number of papers which have had high impact in the community. In particular, in the line of the research of the last years, the group investigated DLs that, on the one hand, are rich enough to express the fundamental constructs of class-based formalisms (ISA between classes, typing of associations, etc.), and on the other hand, admits reasoning tasks that are polynomial in the size of the data. Notably, such DLs allow for reasoning techniques that amount to evaluation of suitable first order queries (somehow incorporating the intensional knowledge provided by the DL knowledge base) on a database instance (representing the extensional level of the DL knowledge base). In [33], a foundational study on a family of DLs showing the above characteristics, called DL-Lite, is provided, and first-order logic based techniques for knowledge base satisfiability, logical implication, and conjunctive query answering over DL-Lite are defined. In [9, 37] query languages more expressive than the language of (union) of conjunctive queries are considered, and techniques for query answering, under a different semantic characterization, over DL-Lite and over other DLs languages are provided. In [10, 41] extensions of DL-Lite are considered, which suitably allows us to profitably link databases to DL ontologies, whereas the problem of updating ontologies at the instance level is addressed in [12]. Conjunctive query containment under description logics constraints has been studied in [34], where algorithms for decidable cases are given, and undecidability of containment of conjunctive queries with inequalities is proved. Also, an in-depth study on data complexity of conjunctive query answering in DLs has been given in [8], where bounds are provided for query answering in several DLs drawing precise boundaries between LOGSPACE, NLOGSPACE-hard, PTIME-hard, and NP-hard DLs. A study on decidability of answering expressive queries over DLs has been instead carried out in [42]. Description Logics are nowadays also playing a central role in ontologies and in the Semantic Web, since they are currently the most used formalisms for building ontologies. Both semantic and computational issues arise when extending DLs with rule-based components. In [25] a general framework for integrating ontologies and rules is defined, which provides for a clear treatment of the above semantic issues. Moreover, general decidability and complexity results for reasoning in such systems combining ontologies and rules are defined. Other studies on the relationship between ontologies and rules

are [24, 26, 40, 18], where integration of Description Logics and logic programming is addressed. Finally we mention that the group is participating in the EU project TONES on reasoning tasks for DL-based ontologies that started on September 2005 and will end in August 2008. The coordinator of the unit in Rome is Giuseppe De Giacomo.

Data integration. Data integration is the problem of combining the data residing at different heterogeneous sources, and providing the user with a unified view of these data, called *global schema*. The interest in this kind of systems has been continuously growing in the last years, both in academy and industry. The Data and Knowledge Bases research group has addressed several among the most important problems that arise in data integration, both from a theoretical and a practical point of view. In particular, data inconsistency in the presence of global integrity constraints has been the subject of several papers produced by the group members. In [20], the problem has been addressed in the simplified setting of a single relational database schema, in the presence of classical key dependencies and exclusion dependencies. Then, a Ph.D. thesis [32] provided a complete picture on efficient data integration under integrity constraints, providing techniques for both classical GAV data integration and consistent query answering in data integration systems, which rely on the use of the state of the practice information federation tools (i.e., powerful DBMSs equipped with advanced federation features). Optimization issues for consistent query answering, well-suited for data integration, have been presented in [38]. Then, principles and formal definitions needed to describe both structured (DL-based) and semi-structured (XML-based) data integration frameworks have been addressed in another Ph.D. thesis [31]. In such a thesis, effective algorithms for consistency checking and query answering in each scenario addressed are provided. Finally, decidability and finite controllability of query processing in databases with incomplete information, and therefore generalizable to data integration under classical sound mapping assumptions, have been studied in [27].

We finally point out that the topic of data integration is addressed in the context of the activity of the DASI lab (`http://www.dis.uniroma1.it/~dasilab/`).

View-based query processing. View-based query processing is the problem of processing a query posed to a database only on the basis of the information on a set of views, which are again queries over the same database. Several papers in the literature show that the problem is relevant in many aspects of database management, including query optimization, data warehousing, data integration, and query answering with incomplete information. In the last year, our research has been mainly focused on the study of the fundamental notions in view-based query processing of rewriting, answering and losslessness, and of the relationship between them. In [35] several of such notions are compared and relationships between them are analyzed. Furthermore, query containment and view-based answering for XML documents is analyzed in [36].

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. It exploits the extraordinary perceptual and cognitive capabilities of humans to literally "have a view" on large and complex information with effectiveness and ease. Last year we focused on clutter reduction for information visualization and quality metrics for assessing the value of visualizations. Visualizations often suffer of distortion effects caused by large volume of data and/or complex configurations of items. The aim of clutter reduction is to reduce the amount of that still providing useful and correct information. Our group has analyzed the problem in depth and provided several recovery techniques which are summarized in [1].

We also explored the idea of using quality metrics as a way to instruct reduction algorithms and to provide an objective feedback to end-users. The results are provided in [7] It is also worth noting that we organized a workshop held in the context of the AVI 2006 conference and named BELIV'06 ("BEyond time and errors: novel evaLuation methods for Information Visualization"). The meeting was organized to discuss about the prominent topic of evaluation in the context of Information Visualization and it resulted in a very successful event.

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 evaluation methodology for mobile devices which resulted in one publication a the last AVI Conference [6].

User interfaces to digital libraries. In this area, we have been involved in user interface design and information visualization in digital libraries (DLs). Our ultimate goal is to develop methodologies, techniques and tools to establish a theoretically motivated and empirically supported frame of reference, so to enable future DL designers and developers to meet not only the technological, but also the user-oriented requirements in a balanced way. In the process, we have been investigating how non-conventional paradigms can be used to access and interact with digital libraries. Non-conventional paradigms are basically interaction and access mechanisms that go beyond the conventional "search" and "search-refinement" mechanisms. An interesting development of the work on non-conventional paradigms in DLs has been a new advanced interaction paradigm based on a Digital Library Shell that supports the users with a new kind of activities in order to develop their own data. Specifically, a user is able to develop small programs that access different DLs, manipulate data, and create new data [14]. Besides investigating non-conventional paradigms, we have been working on Task-centered Information Management in digital libraries. In the process, we have proposed a language to model desktop users' activities that are performed most frequently [11]. Moreover, we have designed an architecture for the overall system [22]. On the same note, we have also been

exploring how context modelling and inference is required in a Task-centered Information Management system to provide task suggestions and make interactions easier [13].

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 [3]. 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. We have also been working on how e-learning stakeholders, learners, and accessibility stakeholders can be involved in the development of accessible e-learning content [4].

Data quality and data cleaning. Electronic data play a fundamental role in today's society and the the number and the importance of the activities that depend on it grows every day. This makes vital not only to guarantee efficiency and manageability of data sources, but also to preserve and improve *Data Quality*. The term *Data Cleaning* denotes the process of detecting and possibly correcting errors and other data quality problems in data sources, either when they are considered in isolation or in the context of data integration processes. A core issue in the context of data cleaning and data integration processes is the the *object identification problem*: to detect multiple data instances that represent the same real-world entity. The term *Record Linkage* denotes the activity of solving the object identification problem in structured data sources. This issue is particularly complex in the absence of shared identifiers (keys), or when shared identifiers are available but they are affected by errors (e.g. accuracy errors). In the first case, it is necessary to choose sets of *match variables* suitable for use as identifiers. In [15] a toolkit to dynamically build record linkage processes is presented. In [28] it is shown how record linkage techniques may be exploited to derive data accuracy measures. Record linkage techniques may allow to match data from disparate sources even when data is anonimyzed. This leads to the risk of privacy violations. When publishing critical data it is thus important to evaluate the risk for privacy. In [19], a general framework for a quantitative analysis of the risk of data disclosures is presented.

Semistructured data models have gained attracted wide interest. In particular, the XML data model is used both as an exchange format for data on the Web, and as a data storage model. Beyond issues already present in the case of structured data, object identification for XML data has to face other issues coming from the hierarchical and flexible nature of this data model, that makes it difficult to define suitable ways of comparing objects. A new similarity measure for XML data is presented in [5, 23]. The measure overcomes issues arising when applying traditional tree-similarity techniques to XML object identification. In [30], a methodology and a system for XML object Identification (named *XPurge*) are presented. The idea of the approach is that comparisons among XML

objects must be performed at two level: *structure* and *data values*. Comparisons at the data value level are driven by the results obtained at the structural level, and performed using a distance which is an improvement of that presented in [23]. The system presented in [30] also employs new techniques for the reduction of the number of comparisons to perform, and has been implemented and experimentally validated on real as well as synthetic data. The quality of data is particularly critical in the context of Cooperative Information Systems (CISs), i.e. distributed and heterogeneous information systems that cooperate requesting and sharing information, constraints, and goals. In [39] a general methodology to evaluate the quality of data, with a specific focus on how to define metrics to assess the quality of XML data, is presented. The paper also discusses how the methodology can be applied in distributed, cooperative environments, and proposes the design of distributed components to measure data quality. The experience gained working on several different research issues related to data quality led to the publication of the book [29], targeted to researchers.

Scientific databases are often *curated*: their contents are subject to continuous revision activities. Such activities include correction and annotation. Annotations play a central role in many curated databases, and their value is often comparable to that of the data they complement. However, DBMS's often lack support for storing and querying annotations. The paper [17] introduces an annotation-oriented data model and algebra, that allows to manipulate and query data and annotations altogether, and presents MONDRIAN, an Annotation Management System based on such model. In [16] a full-featured front-end to the MONDRIAN system, that allows both graphical and algebraic manipulation of annotated data.

Members of the group are involved in the research activities of the IFIP 2.6 group on data semantics. They contributed to a study concerning "emergent semantics systems", i.e. P2P-based systems in which the semantic interoperability problem is addressed in a bottom-up fashion starting from interactions among participating peers [2].

Journals

[1] E. Bertini and G. Santucci. Give chance a chance- modeling density to enhance scatter plot quality through random data sampling. *Information Visualization*, 5(2):95–110, 2006.

[2] P. Cudrè-Mauroux, K. Aberer, A. I. Abdelmoty, T. Catarci, E. Damiani, A. Illaramendi, M. Jarrar, R. Meersman, E. J. Neuhold, C. Parent, K.-U. Sattler, M. Scannapieco, S. Spaccapietra, P. Spyns, and G. D. Trè. Viewpoints on emergent semantics. *Journal of Data Semantics VI*, pages 1–27, 2006.

[3] S. Gabrielli, V. Mirabella, S. Kimani, and T. Catarci. A boosting approach to e-content development for learners with special needs. *Educational Technology and Society Journal*, 9(4):17–26, 2006.

[4] M. D. Marsico, S. Kimani, V. Mirabella, K. L. Norman, and T. Catarci. Enhancing the development of accessible e-learning content by human involvement. *Universal Access in the Information Society (UAIS) Journal*, 5(2), 2006.

[5] D. Milano, M. Scannapieco, and T. Catarci. Structure-aware XML object identification. *IEEE Data Eng. Bull.*, 29(2):67–74, 2006.

Conference proceedings

[6] E. Bertini, S. Gabrielli, and S. Kimani. Appropriating and assessing heuristics for mobile computing. In *Proceedings of AVI*, pages 119–126, 2006.

[7] E. Bertini and G. Santucci. Visual quality metrics. In *Proc. of the 2006 AVI workshop on BEyond time and errors: novel evaluation methods for Information Visualization*, 2006.

[8] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini, and R. Rosati. Data complexity of query answering in description logics. In *Proc. of the 10th Int. Conf. on the Principles of Knowledge Representation and Reasoning (KR 2006)*, pages 260–270, 2006.

[9] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini, and R. Rosati. Epistemic first-order queries over description logic knowledge bases. In *Proc. of the 2006 Description Logic Workshop (DL 2006)*. CEUR Electronic Workshop Proceedings, http://ceur-ws.org/Vol-189/, 2006.

[10] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini, and R. Rosati. Linking data to ontologies: The description logic DL-Lite$_A$. In *Proc. of Proc. of 2nd Workshop on OWL: Experiences and Directions (OWLED 2006)*, 2006.

[11] T. Catarci, B. Habegger, A. Poggi, A. Dix, Y. Ioannidis, A. Katifori, and G. Lepouras. Intelligent user task oriented systems. In *Proceedings of the Second SIGIR Workshop on Personal Information Management (PIM)*, 2006.

[12] G. De Giacomo, M. Lenzerini, A. Poggi, and R. Rosati. On the update of description logic ontologies at the instance level. In *Proc. of the 21st Nat. Conf. on Artificial Intelligence (AAAI 2006)*, 2006.

[13] A. Dix, T. Catarci, B. Habegger, Y. Ioannidis, A. Kamaruddin, A. Katifori, G. Lepouras, A. Poggi, and D. Ramduny-Ellis. Intelligent context-sensitive interactions on desktop and the web. In *Proceedings of the International AVI'2006 Workshop on Context in Advanced Interface*, 2006.

[14] Y. Dubinsky, T. Catarci, and S. Kimani. Active data and the digital library shell. In *Proceedings of the International Workshop on Digital Libraries in the Context of Users' Broader Activities (DL-CUBA) at the Joint Conference on Digital Libraries (JCDL) 2006*, 2006.

[15] M. Fortini, M. Scannapieco, T. Tosco, and T. Tuoto. Towards an open source toolkit for building record linkage workflows. In *SIGMOD Workshop on Information Quality in Information Systems, IQIS'06, Chicago, IL, USA*, 2006.

[16] F. Geerts, A. Kementsietsidis, and D. Milano. *i*MONDRIAN: A visual tool to annotate and query scientific databases. In *Advances in Database Technology - EDBT 2006, 10th International Conference on Extending Database Technology, Munich, Germany, March 26-31*, 2006.

[17] F. Geerts, A. Kementsietsidis, and D. Milano. MONDRIAN: Annotating and querying databases through colors and blocks. In *Proceedings of the 22nd International Conference on Data Engineering, ICDE 2006, Atlanta, GA, USA*, page 82, 2006.

[18] I. Horrocks, B. Motik, R. Rosati, and U. Sattler. Can OWL and logic programming live together happily ever after? In *Proceedings of the Fifth International Semantic Web Conference (ISWC 2006)*, pages 501–514, 2006.

[19] G. Lebanon, M. Scannapieco, M. Fouad, and E. Bertino. Beyond k-anonimity: Towards a framework for assessing privacy risk. In *International Conference on Privacy in Statistical Databases (PSD 2006), Roma, Italy*, 2006.

[20] D. Lembo, R. Rosati, and M. Ruzzi. On the first-order reducibility of unions of conjunctive queries over inconsistent databases. In *Proc. of EDBT 2006 Workshops, Revised Selected Papers – Workshop on Inconsistency and Incompleteness in Databases (IIDB 2006)*, pages 358–374, 2006.

[21] M. Lenzerini, E. J. Neuhold, and V. S. Subrahmanian. ODBASE 2006 International Conference (Ontologies, Databases, and Applications of Semantics) PC Co-chairs' message. *OTM Conferences*, 1:697, 2006.

[22] G. Lepouras, A. Dix, A. Katifori, T. Catarci, B. Habegger, A. Poggi, and Y. Ioannidis. Ontopim: From personal information management to task information management. In *Proceedings of the Second SIGIR Workshop on Personal Information Management (PIM)*, 2006.

[23] D. Milano, M. Scannapieco, and T. Catarci. Structure aware xml object identification. In *Proceedings of the First Int'l VLDB Workshop on Clean Databases, CleanDB 2006, September 11, 2006, Seoul, Korea*, 2006.

[24] R. Rosati. DL+log: Tight integration of description logics and disjunctive datalog. In *Proc. of the 10th Int. Conf. on the Principles of Knowledge Representation and Reasoning (KR 2006)*, pages 68–78, 2006.

[25] R. Rosati. Integrating ontologies and rules: semantic and computational issues. In *Reasoning Web 2006*, volume 4126 of *Lecture Notes in Computer Science*, pages 128–151. Springer, 2006.

[26] R. Rosati. The limits and possibilities of combining description logics and Datalog. In *Proceedings of the Second International Conference on Rules and Rule Markup Languages for the Semantic Web (RuleML 2006)*, 2006.

[27] R. Rosati. On the decidability and finite controllability of query processing in databases with incomplete information. In *Proc. of the 25th ACM SIGACT SIGMOD SIGART Symp. on Principles of Database Systems (PODS 2006)*, pages 356–365, 2006.

Articles in books

[28] A. Boggia, A. Pavone, L. Pizzicannella, and M. Scannapieco. Tecniche e metodi sperimentali per la misurazione dell'accuratezza dei dati toponomastici. In P. Falorsi, A. Pallara, and A. Russo, editors, *L'Integrazione di Dati di Fonti Diverse: Tecniche e Applicazioni del Record Linkage e Metodi di Stima Basati sull'Uso Congiunto di Fonti Statistiche e amministrative*. Franco Angeli, 2006.

Book

[29] C. Batini and M. Scannapieco. *Data Quality: Concepts, Methodologies and Techniques*. Springer-Verlag, 2006.

Ph.D. thesis

[30] D. Milano. *Structure-Aware XML Object Identification*. PhD thesis, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006.

[31] A. Poggi. *Structured and Semi-Structured Data Integration*. PhD thesis, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006.

[32] M. Ruzzi. *Efficient Data Integration under Integrity Constraints: a Practical Approach*. PhD thesis, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006.

Submitted papers, technical reports and others

[33] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini, and R. Rosati. Tractable reasoning and efficient query answering in description logics: The DL-Lite family. Submitted to an International Journal, 2006.

[34] D. Calvanese, G. De Giacomo, and M. Lenzerini. Conjunctive query containment and answering under description logic constraints. *ACM Trans. on Computational Logic*, 2006. To appear.

[35] D. Calvanese, G. De Giacomo, M. Lenzerini, and M. Y. Vardi. View-based query processing: On the relationship between rewriting, answering and losslessness. *Theoretical Computer Science*, 2006. To appear.

[36] D. Calvanese, G. De Giacomo, M. Lenzerini, and M. Y. Vardi. Regular xpath: Constraints, query containment and view-based answering for XML documents. Manuscript, 2006.

[37] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini, and R. Rosati. EQL-ite: Effective first-order query processing in description logics. In *Proceedings of the Twentieth International Joint Conference on Artificial Intelligence (IJCAI 2007)*, pages 274–279, 2007.

[38] T. Eiter, M. Fink, G. Greco, and D. Lembo. Repair localization for query answering from inconsistent databases. Submitted to an International Journal.

[39] D. Milano, M. Scannapieco, and T. Catarci. Measuring and diffusing data quality in a peer-to-peer architecture. *International Journal of Enterprise Information Systems (IJEIS), special issue on Interoperability of Enterprise Systems and Applications*, 3(1), 2007.

[40] B. Motik and R. Rosati. A faithful integration of description logics with logic programming. In *Proceedings of the Twentieth International Joint Conference on Artificial Intelligence (IJCAI 2007)*, 2007.

[41] A. Poggi, D. Lembo, D. Calvanese, G. De Giacomo, M. Lenzerini, and R. Rosati. Linking ontologies to data. Submitted to an International Journal, 2006.

[42] R. Rosati. The limits of querying ontologies. In *Proceedings of the Eleventh International Conference on Database Theory (ICDT 2007)*, volume 4353 of *Lecture Notes in Computer Science*, pages 164–178. Springer, 2007.

3.1.5 Distributed Software Architectures

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

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

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

The area comprises several projects, including the following: Progetto MIUR (FIRB 2001) MAIS - Multichannel Adaptive Information Systems; Progetto MIUR (FIRB 2003) eG4M - eGovernment for Mediterranean Countries; Progetto MIUR (PRIN 2005) ESTEEM; Progetto IST “SemanticGOV”; Progetto IST “WORKPAD”; IST Network of Excellence “INTEROP”; IST Network of Excellence “DELOS”.

Group members Roberto BALDONI, Roberto BERALDI, Silvia BONOMI, Tiziana CATARCI, Giuseppe DE GIACOMO, Massimiliano DE LEONI, Fabio DE ROSA, Davide LA MANNA, Domenico LEMBO, Maurizio LENZERINI, Carlo MARCHETTI, Massimo MECELLA, Damiano POZZI, Leonardo QUERZONI, Riccardo ROSATI, Ruggero RUSSO, Sara TUCCI PIERGIOVANNI, Sirio SCIPIONI, Antonino VIRGILLITO.

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

Our research has been particularly focused on automatic service composition. Service composition addresses the situation when a client request cannot be satisfied by any available service, but a composite service, obtained by combining "parts of" available component services, might be used. Results have been presented in [4, 5]. Our techniques are recognized at international level among the first ones which have been proved to be correct wrt the semantics. In particular members of the group delivered invited tutorial on automatic service composition at the ICWS/SCC 2006 Conference.

Other work has been conducted in the area of security for services, namely on the issue of access control [7] and composition in trust-aware communities [6].

Finally, work has been conducted on the issue of orchestration of services, by focusing on substitutability issues [1] and on methodologies on how to build cooperative applications based on orchestrated services [2].

All the previous activities are carried out in the context of the activity of the DASI Lab (`http://www.dis.uniroma1.it/~dasilab/`).

Adaptive Computing. The adaptive computing research activity is devoted to study and analyze adaptive aspects of cooperative information systems in highly mobile contexts, such as 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 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 designing and developing of a platform able to provide a communication software level and to support the development of distributed applications for MANET contexts. Issues related to the definition of process formalisms based on algebraic approaches, and techniques and algorithms supporting process adaptation have been addressed [3, 15, 16]. In addition, a framework able to support adaptive process management in mobile contexts has been presented in [14, 8].

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

Specifically, in [11] a peer-to-peer service-based architecture is proposed for the management of the legislative processes producing laws for the Italian Parliament (jointly with the Italian CNIPA and involved Administrations) [11]. In [12, 13] methodological

issues about eGovernment projects are considered, with a specific multidisciplinary focus considering economics, social sciences and IT issues.

Moreover, the topic of adaptive computing is specifically tailored for designing and developing innovative software infrastructures for supporting collaborative work of human operators in emergency/disaster scenarios [10, 9].

Peer-to-Peer Data Management and Interoperability. Currently computers are changing from isolated systems to entry points to information exchange networks. This change of perspective makes it particularly interesting to study how autonomously developed software applications can actually interoperate. Besides technological problems, which are currently being tackled with success from both industrial and scientific research, one of the most interesting and difficult issues is how to make autonomous applications interoperate at the semantical level. That is, how to make it possible to share a significant fragment of the data and process semantics across different software systems. In (data intensive) peer-to-peer systems, each peer exports data in terms of its own data schema. Interoperation is obtained by defining suitable mappings among the peers' schemas. Peers are autonomous, and such mappings are created and deleted dynamically. One of the fundamental problems in this setting is how to perform query answering on a peer, fully exploiting the data at the various peers which are available to it through the mappings. The group of distributed software architecture has addressed the problem of semantic peer-to-peer data management both from the theoretical and practical view-point. In particular, recent proposals for tackling the problem of modelling peer-to-peer data integration systems has been surveyed in [17]. Also, a specific formalization based on multimodal epistemic logic has been proposed in [18], where the idea is that each peer is a rational agent that exchanges knowledge with other peers. In this same paper, also the issue of possible inconsistencies arising from the interaction between peers is considered, and a nonmonotonic extension of the logic is proposed that is able to repair mutual inconsistent information flowing from different peers. A very recent development on peer-to-peer data management combining together data integration and data exchange (the latter being the problem of physically moving the data from one peer to another, and hence is concerned with materialization issues) has been presented in [20], and poses the basis for future studies. Finally, query reformulation under classical first-order logic formalization of peer-to-peer systems has been addressed in the context of ontology-based peers in [19].

The topic of peer-to-peer data management and interoperability is addressed in the context of the activity of the DASI Lab (`http://www.dis.uniroma1.it/~dasilab/`).

Journals

[1] V. De Antonellis, M. Melchiori, L. De Santis, M. Mecella, E. Mussi, B. Pernici and P. Plebani. A Layered Architecture for Flexible Web Service Invocation. *Software Practice & Experience*, 36(2), 2006.

[2] M. Mecella, B. Pernici. Cooperative Information Systems based on a Service Oriented Approach. *International Journal of Interoperability in Business Information Systems (IBIS)*, vol. 1, no. 3, 2006.

[3] P. Bottoni, F. De Rosa, M. Mecella, and K. Hoffmann. Applying Algebraic Approaches for Modeling Workflows and their Transformations in Mobile Networks. *International Journal of Mobile Information Systems (IJMIS)*, IOS Press, 2(1), 2006

Conference proceedings

[4] D. Berardi, G. De Giacomo, M. Mecella and D. Calvanese. Composing Web Services with Nondeterministic Behavior. *Proc. IEEE International Conference on Web Services (ICWS'06)*, 2006.

[5] D. Berardi, D. Calvanese, G. De Giacomo and M. Mecella. Automatic Web Service Composition: Service-tailored vs. Client-tailored Approaches. *Proc. AISC 2006 – International Workshop jointly with ECAI 2006*, 2006.

[6] F. Cheikh, G. De Giacomo and M. Mecella. Automatic Web Services Composition in Trust-aware Communities. *Proc. 3rd ACM Workshop on Secure Web Services*, 2006.

[7] M. Mecella, M. Ouzzani, F. Paci and E. Bertino. Access Control Enforcement for Conversation-based Web Services. *Proc. 15th World Wide Web Conference (WWW 2006)*, 2006.

[8] M. de Leoni, F. De Rosa and M. Mecella. MOBIDIS: A Pervasive Architecture for Emergency Management. *Proc. 4th International Workshop on the Distributed and Mobile Collaboration (DMC 2006)*, 2006.

[9] M. Mecella, M. Angelaccio, A. Krek, T. Catarci, B. Buttarazzi and S. Dustdar. WORKPAD: an Adaptive Peer-to-Peer Software Infrastructure for Supporting Collaborative Work of Human Operators in Emergency/Disaster Scenarios. *Proc. International Symposium on Collaborative Technologies and Systems (CTS 2006)*, 2006.

[10] T. Catarci, F. De Rosa, M. de Leoni, M. Mecella, M. Angelaccio, S. Dustdar, B. Gonzalvez and G. Iiritano. WORKPAD: 2-Layered Peer-to-Peer for Emergency Management through Adaptive Processes. *Proc. 2nd International Conference on Collaborative Computing: Networking, Applications and Worksharing*, 2006.

[11] L. De Santis, C. Lupo, C. Marchetti and M. Mecella. The x-Leges System: Peer-to-Peer for Legislative Document Exchange. *Proc. 5th European Conference on eGovernemt (eGOV 2006)*, 2006.

[12] C. Batini, D. Ciriaci, M. Corsi, A. Maurino, R. Russo and S. Scipioni. Multidisciplinary Models and Guidelines for e-Procurement Projects: The Design Phase. *Proc. eGovernment Workshop 06* (Brunel University, West London UB8 3PH, United Kingdom), ISBN 1-902316-47-9. Available on line: `http://www.iseing.org/egov/eGOV06/proceedings.htm`.

[13] C. Batini, F. Cabitza, G. Cammarota, D. Ciriaci, M. Corsi, A. Maurino, R. Russo, S. Scipioni and M. Telaro. Multidisciplinary Models and Guidelines for eProcurement Projects: the eReadiness Phase. *Proc. 6th IFIP conference on e-Commerce, e-Business, and e-Government (I3E 2006)*, 2006.

Submitted papers, technical reports and others

[14] F. De Rosa, M. Mecella, et al. E-Services. In B. Pernici, editor, *Mobile Information System*, Springer-Verlag, ISBN-10 3-540-31006-1, 2006.

[15] F. De Rosa, P. Bottoni, M. Mecella, and S. Dustdar. Modelling Adaptive Process Management in Mobile Network Scenarios through Ineritance Relations, Technical report 06-32, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006, downloadable at `http://www.dis.uniroma1.it/~derosa/whitepapers/DBMD_TechReport.pdf`

[16] M. de Leoni, F. De Rosa, S. Dustdar, and M. Mecella. Adaptive Process Management for Homeland Emergency Applications. Technical report 06-3, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006, downloadable at `http://www.dis.uniroma1.it/~derosa/whitepapers/dDM_TechReport.pdf`

[17] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini and R. Rosati. Data Management in Peer-to-Peer Data Integration Systems. In R. Baldoni, G. Cortese, F. Davide, and A. Melpignano, editors, *Global Data Management*, volume 8 of *Emerging Communication: Studies in New Technologies and Practices in Communication*, pages 177–201. IOS Press, 2006.

[18] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini and R. Rosati. Inconsistency Tolerance in P2P Data integration: an Epistemic Logic Approach. Submitted to an international journal, 2006.

[19] D. Calvanese, G. De Giacomo, D. Lembo, M. Lenzerini and R. Rosati. What to Ask to a Peer: Query Reformulation over Ontology-based Peers. Submitted to an international journal, 2006.

[20] G. De Giacomo, D. Lembo, M. Lenzerini and R. Rosati. On Reconciling Data Exchange, Data Integration, and Peer Data Management. Submitted to an international conference, 2006.

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

Roberto Baldoni leads the MIDdleware LABoratory (MIDLAB), he is a member of the technical board of Sapienza Innovazione and of the European Security & Dependability Task Force. He belongs to the Executive Board of the ReSIST NoE and for the industrial side he participated in the Finmeccanica Technical Board for EU relationships. He participated in the working group for the definition of the next generation systems for Italian e-government (Servizio Pubblico di Cooperazione) and he leads the participation of La Sapienza within the EU project SemanticGov. Moreover, he has been invited to chair the 26th edition of the Symposium on Reliable Distributed Systems that will be held in Bejing. In 2006, he has been invited several times by the EU commission to deliver talks in the context of a series of Summit Meetings EU-NSF for defining common research strategies in the context of Cyber Security.

Roberto Beraldi has been Program Chair of the International Workshop on Dynamic Distributed Systems (IWDDS); he was involved in the PC of the International Symposium on Reliable Distributed Systems (SRDS), and is currently in the the Knowledge Base board of ReSIST NoE.

During 2006 members of the group were involved in the Program Committees of many prestigious international conferences and workshops like ICDCS, DSN, SSS, ICPS, SAC, IWDDS, and ADSN.

The Distributed Systems group has strong relationships with the most prestigious research institutions worldwide. In 2006, members of the group did joint work with research scientists of the following institutes and industries: INRIA (France), UPM (Spain), LAAS (Toulouse, France), Hebrew University of Jerusalem (Israel), Technion (Haifa, Israel), IBM Haifa (Israel), EPFL (Lousanne, Switzerland), University of Texas at Austin (USA), TELECOM Italia (Italy), SELEX-SI (Italy), University of California Irvine (USA), Univ. of Rennes (France), Technical University of Darmstad (Germany), Univ of Paris VI (France), Cornell Univ. (USA), Technical Univ. of Dresden (Germany), GeorgiaTech (USA), Humbold Univ. (Germany).

Moreover in 2006, Alessia Milani and Leonardo Querzoni finished their PhD program in the context of a co-tutorage with the Univ. of Rennes and the Universidad Politecnica de Madrid (UPM) respectively.

The Distributed Systems group is presently involved in the following research projects:
International projects: Semantic.gov (EU-IST), ReSIST (EU-IST); ESTEEM (MIUR), EG4M (MIUR), MAIS (MIUR), IS-MANET (MIUR).
Industrial projects: “QoS for lookup mechanisms in peer-to-peer systems” (Telecom Italia Laboratories), “Large-scale data distribution through publish/subscribe systems” (Telecom Italia Learning Services), “Implementing the Data Distribution Service specification in wide-area settings” (Selex-SI/Finmeccanica), “Middleware infrastructures for alarms

management in complex systems" (Selex-SEMA/Finmeccanica).

Staff of the Distributed Systems group also participates in the MIDLAB Laboratory. The primary goal of MIDLAB is to support leading-edge research and development on middleware bridging the gap between the latest theoretical research results and the current technologies. In particular main MIDLAB targets are the study, the design and analysis of novel middleware platforms able to increase the robustness of information exchanging with respect to reliability, consistency, predictability and security.

Faculty members: Roberto BALDONI, Roberto BERALDI, Giacomo CIOFFI.
Post-docs: Kleoni IOANNIDOU, Vivien QUÉMA, Sara TUCCI PIERGIOVANNI.
PhD students: Silvia BONOMI, Adnan Noor MIAN, Alessia MILANI, Leonardo QUERZONI, Sirio SCIPIONI.
Adjunt Researchers: Stefano CIMMINO, Carlo MARCHETTI, Antonino VIRGILLITO.
Visitors: Gregory CHOCKLER, Jean-Michel HÉLARY, Ricardo Jiménex-Peris, Ron LEVY, Miroslaw MALEK, Marta PATIÑO-MARTINEZ, Michel RAYNAL, Neeraj SURI.

Theory of Distributed Computing

Data Consistency. A well-known approach to augment the availability of an object is using different copies (replicas) of the object at different sites; the issue in this case is maintaining some form of consistency among all replicas. Traditionally, many systems running on local area networks provide so-called single copy semantics that gives the user the illusion of accessing a single, highly available object. Typical solutions require users to access a quorum of replicas, to acquire exclusive locks on data they wish to update or to agree on a total order of updates to be applied at each replica. Maintaining single-copy semantics in a worldwide deployed system is theoretically impossible. It is thus necessary to use (weaker) consistency criteria. This is precisely what *eventual consistency* provides. It guarantees that whatever the current state of the replica, if no new updates are issued and replicas can communicate freely for a long enough period, the contents of all replicas eventually become identical.

In [15] a replication protocol that ensures eventual consistency in large-scale distributed systems subject to network partitions and asynchrony is presented. Contrarily to solutions appeared in the literature, the proposed protocol does not rely on any form of consensus, which would lead to block the replicas in case of partitions and asynchrony. Our protocol instead ensures that updates are continuously gossiped and applied to the replicas and no two updates are ever performed in a different order. Gaps might occur during periods of unreliable communication. They are filled whenever connectivity is provided, and consistency is then eventually ensured, but without any conscious commitment. That is, there is no point in the computation when replicas know that consistency is achieved. This unconsciousness is the key to tolerating perpetual asynchrony with no consensus support.

Distributed Shared Memory. Causal consistency is deeply studied in the context of traditional distributed systems where the number of processes is fixed and a priori known. Traditionally, DSM implementations rely on a distributed memory consistency system (MCS) to enforce a given consistency criterion. Usually the MCS supports complete replication of shared variable at each node accessing the shared memory. To complete existing results concerning DSM in traditional distributed systems, we studied [2, 21] the cost in terms of maintaining causal consistency when the MCS level support partial replication. We show that partial replication has the same inter-process communication cost than complete replication, if shared variables distribution is not a priori known.

Traditional solutions are not suitable for emerging dynamic distributed systems (e.g. peer-to-peer). Emerging system paradigms are attractive for the huge amount of memory and processing power they may provide. But they are intrinsically uncertain due to continuous node joins and departures. Usually user-driven, such dynamic behavior introduces a complex time-varying nature of nodes availability, i.e. any process in the system can leave the computation at any time deliberately or by crashing. A process usually leaves the system without notification. Maintaining data consistency in such settings is a basic problem. Strict consistency criteria are hard or even impossible to enforce in dynamic systems due to the lack of data persistency (e.g. written values) caused by the continuous change in system membership. For this reason, we adapted traditional causal consistency to obtain a memory semantics weak enough to be implemented in such dynamic systems but strong enough to allow computational progress, namely weakly persistent causal consistency. We implemented a weakly persistent causal consistent distributed shared memory over an asynchronous message passing system characterized by (i) infinitely many processes and (ii) high dynamics. Our shared memory implementation enjoys the desirable property of maintaining legal read with respect to causality all the time regardless of periods affected by high dynamics and of leveraging quiescent periods to bring forward a computation perceived in the same way by all clients joining the system along the time.

Dynamic distributed systems. In the context of asynchronous distributed systems with infinitely many processes, we study the fundamental problem of maintaining connectivity among a set of processes forming a group in a dynamic context where processes can join and leave at any time the group and processes have a partial knowledge of other processes belonging to the group.
In this setting we provided a few impossibility results and a deterministic protocol solving the connectivity problem. Moreover, in such a dynamic context, we gave (i) the specification of a service of reliable broadcast showing that it is equivalent to our connectivity problem and (ii) a specification of a service of atomic broadcast inside the group and a solution based on the protocol presented to solve the connectivity problem [18].

Peer-to-Peer Systems *Unstructured Systems.* P2P systems are at present a widespread technology as well as a hot research topic. A P2P system is a highly dynamic distribute system in which nodes perpetually join and leave. For these characteristics, a P2P sys-

tem can reach a potentially infinitely wide scale with a transient population of nodes. Overlay networks have emerged as viable solutions to support a P2P application in an efficient and scalable manner maintaining a satisfactory level of reliability. An overlay is a logical network built on top of – and generally independently from – the underlying physical computer network, by the peers (nodes) of the P2P system. *Unstructured* overlay networks have recently emerged as an effective support for large scale dissemination and flooding-based content searching. An unstructured overlay shows good global properties like connectivity (for reliability), low network diameter and constant-degree (for scalability) without relying on a deterministic topology. *Overlay maintenance* is the fundamental problem consisting in preserving the topological properties of an overlay despite continual arrivals and departure of nodes. variants of the problem under different kinds of assumptions, for the problem and its underlying computational model have never been precisely defined.

Our research in this area has focused on the experimental evaluation of current overlay maintenance protocols in a common framework in order to understand their limits and to make a comparison of different solutions. More specifically we compared [13] two overlay maintenance protocols well suited to unstructured P2P systems, namely SCAMP and Cyclon, in an event-based simulation setting including concurrent and interleaved join and leave operations as well as variable message transfer delay. Our study shows how for both protocols, under a continuous and concurrent replacement of nodes, permanent partitioning of the overlay arises after a very small number of join/leave operations.

We further investigated the effects of churn in the context of the overlay network and identified [26] a second effect connected to churn, namely network erosion. Network erosion is a phenomenon, caused by churn, concerning the progressive isolation of single nodes or tiny clusters that lose connectivity with the main cluster of the overlay network. We have shown, through an experimental study, how erosion affects overlay network connectivity and pointed out that even a strongly connected overlay networks, when exposed to continuous churn, can be disgregated in a relatively short time. We proposed a connection recovery mechanism, applicable to existing overlay management protocols, which is able to collaboratively detect node isolation and the presence of small clusters. This mechanism was shown to be effective in reducing the erosion of an overlay network exposed to continuous churn and to quickly recover its connectivity as soon as churn ends.

DHT-based Structured Systems. Peer-to-peer decentralized systems (P2P) have become extremely popular in the latest years. However, most P2P systems still consist in simple applications such as file sharing or chat systems. The main reason is that complex applications often require powerful communication primitives that nowadays are not offered by P2P systems. Our research work [29] faced this issue addressing the realization of mutual exclusion on top of existing P2P structured overlay infrastructures (Distributed Hash Tables - DHTs). Our aim was to provide consistency based on distributed mutual exclusion via quorum systems. We conducted a simulation study that showed how quorum systems directly applied to P2P networks are not scalable due to the high load imposed

onto the underlying network. Basing our work on these results we introduced some design principles for both hierarchical grid-based and tree-based quorum systems that help to boost their performance. These design principles consist in dynamic and decentralized selection of quorums and in the exposition and exploitation of internals of the DHT such as the finger table. Our study showed that, combining both design principles, it is possible to minimize the number of visited sites and the latency needed to obtain a quorum.

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.

Software replication of stateful services is typically implemented using two-tier architectures, in which clients directly interact with replicas running distributed agreement protocols for ensuring consistency. In general, performance of these protocols is sensitive to network delays, which might consequently reduce service availability. Therefore, we have introduced three-tier software replication, in which agreement protocols run in an dedicated tier (detached from clients and replicas) that can be independently deployed in a controlled and stable part of the network.

We showed [4, 5] how to design middleware services that exploit a three-tier architecture to implement replication protocols that enforce a strong consistency criterion, i.e. to implement transparent replication for fault tolerance of a service whose replicas are deployed on a wide area network. A three-tier architecture separates the operation of ordering of the requests coming from clients, executed by the middle-tier, from their actual execution done by the replicas (i.e., the end-tier). In this way placement of replicas is left to the service provider while the placement of middle-tier replicas is in charge to the protocol designer. The latter can then deploy them on a stable part of the distributed system to ensure a fast termination of the agreement algorithm avoiding undesirable service unavailability periods. The three-tier protocol is fault-tolerant and ensures termination (a client will eventually receive a reply) even when only one end-tier replica is correct (i.e., non-crashed). A proof of concept of our protocols has been developed in the context of the Interoperable Replication Logic (IRL) system, which exploits a three-tier architecture and specialized protocols to implement transparent replication of distributed objects compliant with the Common Object Request Broker (CORBA) standard.

We also analyzed [17], through an experimental study, the performance of different replication protocols (i.e., active, passive, and three-tier replication) using a simplified wide-area network model that considers two types of behaviors for channels, i.e., normal (small and predictable latency variations), and slow (high and unpredictable latency variations). This channel model is instantiated using traces of real Internet latencies measured sending HTTP requests to Internet web-sites at varying rates. The results show

how the end-to-end latency of each replication protocol is related to the number of slow channels. Results have demonstrated that the availability of a service replicated through a three-tier architecture is less affected from channel slow-downs.

Group toolkits. Total Order (TO) is a widely investigated communication abstraction implemented in several distributed systems. Intuitively, a TO primitive ensures that processes of a message-passing distributed system deliver the same sequence of messages. This property is extremely useful for implementing several applications. Implementations of the total order, namely group communication toolkits are nowadays widely recognized as good candidates for implementing systems with stringent nonfunctional requirements, e.g. fault-tolerance, timeliness, throughput, scalability. In this context, group communication systems have several success stories showing efficiency and effectiveness of some well-known features easing the achievement of fault tolerance and high availability. However, there are several subtleties that still deserve clarification, especially among practitioners that can get confused by the relevant amount of theoretical work done in this area. Our research on this topic has the aim of providing assistance to practitioners in finding the TO implementation that best matches both applications correctness and performance requirements. We presented [1]a simple yet meaningful performance analysis of the implementations in real systems of some TO primitives. The results show that the performance of a TO primitive depends on the combination of three factors, (i) the enforced TO specification, (ii) the TO protocol used to implement that specification, and (iii) the way the protocol is implemented.

Communication Middleware. A communication middleware is a software tool aimed at the diffusion of information over a large-scale distributed system spanning an Internet-size network. 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. The success of this communication paradigm is mainly due to the capacity of publish/subscribe to completely decouple communication participants, thus allowing the development of applications that are more tolerant to communications asynchrony. Participants to a publish/subscribe system does not interact directly but they are decoupled by a distributed event service that implements routing of notifications from producers to consumers. Producers of information (publishers) issue notifications to the event service. These are delivered by the event service to all subscribers that declared interest in it.

We realized a comprehensive survey of the state-of-the-art in the publish/subscribe area [30]. In particular, we developed a generic layered architecture of a pub/sub system, by identifying and classifying the common elements of any system. For each layer, we surveyed the various algorithms that have been proposed, focusing on the assumption they rely on and the constraints they impose on other layers. Any existing pub/sub solutions can be obtained by plugging a specific algorithm at each layer, including those tailored for very specific environments such as Mobile Ad-Hoc Networks or Sensor Networks.

Our studies also focalized on the introduction of advanced clustering techniques aimed at improving the performance of event diffusion mechanisms both in static controlled settings [24] and large scale peer-to-peer environments [23, 33]. These works show

how interest-based clustering of system participants is an effective way to greatly reduce the average amount of traffic generated to diffuse each single notification.

The introduction of the publish/subscribe communication paradigm in peer-to-peer applications poses problems related to the intrinsic dynamic behaviour of such applications. In this context, we selected two basic algorithms for event diffusion and studied [11, 14] their behavior in the context of peer-to-peer networks characterized by a high frequency of nodes arrivals and departures. Our study shows that routing information becomes rapidly obsolete when nodes in the system frequently changes. The introduction of an expiration mechanism for subscriber interests can greatly aid reducing the waste of memory and maintain notification routing information accurate.

Finally, we studied and analyzed the Data Distribution Service specification proposed by OMG [6]. The DDS describes a publish/subscribe based communication middleware able to provide, on request, predictable levels of service with respect to reliability, timeliness and notification ordering. Our studies are currently focalized on the problem of implementing the DDS specification in wide area setting were most QoS properties can be hardly guaranteed.

Journals

[1] R. Baldoni, S. Cimmino and C. Marchetti. A Classification of Total Order Specifications and its Application to Fixed Sequencer-based Implementations, In *Journal of Parallel and Distributed Computing*, volume 66, num. 1, pages 108-127, 2006.

[2] R. Baldoni, A. Milani and S. Tucci Piergiovanni. Optimal Propagation-based Protocols implementing Causal Memories, *Distributed Computing*, volume 18, pages 461-474, 2006

[3] R. Beraldi, L. Querzoni and R. Baldoni. A hint-based probabilistic protocol for unicast communications in MANETs, *Ad Hoc Networks*, volume 4, num. 5, pages 547-566, 2006.

[4] C. Marchetti, R. Baldoni, S.T. Piergiovanni and A. Virgillito,. Fully Distributed Three-Tier Active Software Replication, In *IEEE Transactions on Parallel and Distributed Systems*, 2006.

Articles in books

[5] M. Adorni, F. Arcelli, R. Baldoni, R. Beraldi, A. Limonta, M. Locatelli, P. Losi, C. Marchetti, A. Milani, L. Querzoni, C. Raibulet, M. Sarini, C. Simone, F. Tisato, S. T. Piergiovanni, A. Virgillito and G. Vizzari. Middleware and Architectural Reflection, Chapter in *Mobile Information Systems*, Springer, 2006.

[6] A. Corsaro, L. Querzoni, S. Scipioni, S. T. Piergiovanni and A. Virgillito. Quality of Service in Publish/Subscribe Middleware, Chapter in *Global Data Management*, IOS Press, 2006.

[7] A. Milani, L. Querzoni and S. T. Piergiovanni. Data Object Storage in Large Scale Distributed Systems, Chapter in *Global Data Management*, IOS Press, 2006.

[8] G. Cortese, F. Morabito, F. Davide, A. Virgillito, R. Beraldi, V. Quéma. Data aggregation in large scale dist. systems, Chapter in *Global Data Management*, IOS Press, 2006.

Book

[9] R. Baldoni, G. Cortese, F. Davide and A. Melpignano (Editors), *Global Data Management*, IOS Press, 2006.

Conference proceedings

[10] E. Anceaume, A. K. Datta, M. Gradinariu, G. Simon and A. Virgillito. A Semantic Overlay for Self-* Peer-to-Peer Publish/Subscribe, In *Proceedings of the 26th IEEE International Conference on Distributed Computing Systems* (ICDCS), 2006.

[11] R. Baldoni. Publish/Subscribe on the top of Overlay networks: when subscription dynamics meet churn, In *Proceedings of the 26th IEEE International Conference on Distributed Computing Systems Workshops* (ICDCSW), 2006.

[12] R. Baldoni, R. Beraldi, A. Mian. Survey of Service Discovery Protocols in Mobile Ad Hoc Networks, In *Proceedings of the 6th International Workshop on Innovative Internet Community Systems*, 2006.

[13] R. Baldoni, S. Bonomi, L. Querzoni, A. Rippa, S. T. Piergiovanni, and A. Virgillito. Evaluation of Unstructured Overlay Maintenance Protocols under Churn. *International Workshop on Dynamic Distributed Systems* (IWDDS). In *Proceedings of the 26th IEEE International Conference on Distributed Computing Systems Workshops* (ICDCSW), 2006.

[14] R. Baldoni, G. Cortese, F. Morabito, L. Querzoni, S. T. Piergiovanni, and A. Virgillito. On The Accuracy of Event Distribution Lists for Publish/Subscribe. *5th International Workshop on Distributed Event-Based Systems* (DEBS). In *Proceedings of the 26th IEEE International Conference on Distributed Computing Systems Workshops* (ICDCSW), 2006.

[15] R. Baldoni, R. Guerraoui, R. Levy, V. Quema and S. Tucci Pergiovanni. Unconscious Eventual Consistency with Gossips, In *Proceedings of the 8th International Symposium on Stabilization, Safety and Security of Distributed Systems* (SSS), 2006.

[16] R. Baldoni, M. Malek, A. Milani and S. Tucci Piergiovanni. Weakly-Persistent Causal Objects In Dynamic Distributed Systems, In *Proceedings of IEEE Symposium on Reliable Distributed Systems* (SRDS), 2006.

[17] R. Baldoni, C. Marchetti and A. Virgillito. Impact of WAN Channel Behavior on End-to-end Latency of Replication Protocols, In *Proceedings of the 6th European Dependable Computing Conference* (EDCC), 2006.

[18] R. Baldoni, S. Scipioni and S. Tucci Piergiovanni. Communication Channel Management for Maintenance of Strong Overlay Connectivity, In *Proceedings of the 11th IEEE International Symposium on Computers and Communications* (ISCC), 2006.

[19] R. Beraldi. A directional gossip protocol for path discovery in MANETs, *Workshop on Wireless Ad hoc and Sensor Networks* (WWASN), 2006.

[20] A. K. Datta, M. Gradinariu and A. Virgillito. Deterministic Delta-Connected Overlay for Peer-to-Peer Networks, In *Proceedings of the 9th IEEE International Symposium on Object and component-oriented Real-time distributed Computing* (ISORC), 2006.

[21] J. Hélary and A. Milani. About the efficiency of partial replication to implement Distributed Shared Memory, In *Proceedings of the 2006 International Conference on Parallel Processing* (ICPP), 2006.

Submitted papers, technical reports and others

[22] L. Allulli, R. Baldoni, L. Laura and S. Tucci Piergiovanni. On the Complexity of Removing Z-cycles from a Checkpoint and Communication Pattern, Submitted to an international journal.

[23] R. Baldoni, R. Beraldi, V. Quéma, L. Querzoni, S. Tucci-Piergiovanni and A. Virgillito. A Scalable P2P Architecture for Topic-Based Event Dissemination, Submitted to an international conference.

[24] R. Baldoni, R. Beraldi, L. Querzoni and A. Virgillito. Efficient Publish/Subscribe through a Self-Organizing Broker Overlay and its Application to SIENA, (to appear) *The Computer Journal*, Oxford University Press, 2006.

[25] R. Baldoni, M. Bertier, M. Raynal, and S. Tucci Piergiovanni. *Looking for a Definition of Dynamic Distributed Systems*, Submitted to an international conference.

[26] R. Baldoni, S. Bonomi, L. Querzoni, A. Rippa, S. T. Piergiovanni and A. Virgillito. Fighting Erosion in Dynamic Large-Scale Overlay Networks, To appear in *Proceedings of the IEEE International Conference on Advanced Information Networking and Applications* (AINA), 2007.

[27] R. Baldoni, A. Corsaro, L. Querzoni, S. Scipioni, S. Tucci Piergiovanni. An Adaptive Coupling-Based Algorithm for Internal Clock Synchronization of Large Scale Dynamic Systems, Submitted to an international conference.

[28] R. Baldoni, J.-M. Hélary and S Tucci Piergiovanni. A Component-Based Methodology to Design Arbitrary Failure Detectors for Distributed Protocols, To appear in *Proceedings of the 10th IEEE International Symposium on Object and component-oriented Real-time distributed Computing* (ISORC), 2007.

[29] R. Baldoni, R. Jiménez-Peris, M. Patiño Martinez, L. Querzoni and A. Virgillito. Dynamic Quorums for DHT-based P2P Networks, Submitted to an international journal.

[30] R. Baldoni and A. Virgillito. Distributed Event Routing in Publish/Subscribe Communication Systems: a Survey, Technical report, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006.

[31] S. Tucci Piergiovanni and Roberto Baldoni. Self-Maintenance of Eventual Connectivity in Overlay Networks, Submitted to an international journal.

Ph.D. thesis

[32] A. Milani. *Causal Consistency in static and dynamic distributed systems*, PhD Thesis, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006.

[33] L. Querzoni. *Techniques for Efficient Event Routing*, PhD Thesis, Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", 2006.

3.1.7 Parallel and Distributed Computing

The research activity of the Parallel and Distributed Computing group focuses on various aspects spanning from theory to modeling, design and implementation in the context of both computing and service oriented applications and platforms. 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.

In 2006 members of the group were involved in several Program Committees of prestigious International Conferences (like NCA, ANSS, PADS, DS-RT, IPDPS/DPDNS, ICAS/ICNS) or even had chairmanship positions for those same Conferences.
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). Some of the members of the group are also co-founders of IRIANC.
The Parallel and Distributed Computing group is presently involved in the following research projects: MURST FIRB "Wide-scalE, Broadband, MIddleware for Network Distributed Services (WEBMINDS)"; MURST FIRB "Performance Evaluation of Complex Systems".

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

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

Our focus is on reliability in multi-tier systems with stateless middle-tier servers, in their most general configuration where the application logic is allowed to execute atomic transactions against a set of autonomous distributed back-end databases, e.g., as in the context of multiple parties involved within the same business process. For this kind of systems, some authors have recently proposed a reliability framework called e-Transaction (exactly-once Transaction), which is specified via a set of seven properties belonging to the following three categories: *Termination*, *Agreement* and *Validity*. Termination guarantees the liveness of the client-initiated interaction from a twofold prospective: not only it is guaranteed that a client does not remain indefinitely waiting for a response, but also that no database server maintains pre-committed data locked for an arbitrarily long time interval. Agreement embodies the safety properties of the system, ensuring both atomicity of the distributed transaction, and at-most-once semantic for the processing of client requests. Finally, Validity restricts the space of possible results to exclude meaningless ones, e.g. where results are invented or transactions are committed even though some database is unable to pre-commit them. In this context we have proposed innovative e-Transaction protocols that reveal performance effective (i.e. they requires less, or at most the same, message rounds and eager logs as literature protocols), and that have the distinguishing feature of ensuring the e-Transaction properties while relying on less strict, or even no assumptions on the accuracy of failure detection, hence being employable in a pure asynchronous system. Compared to state of the art protocols, our proposals results 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. We note that complete lack of accuracy in the failure detection may lead to the pathological situation in which false failure suspicions are issued indefinitely while handling the end-to-end interaction. In such a scenario, an extermination based approach before re-issuing requests, might yield to an indefinite sequence of aborts of on-going work carried out on behalf of a given client by falsely suspected servers. On the other hand, if no extermination is performed, re-issuing requests might lead to blocking situations (due to pre-commit locks) involving both newly activated and previously activated work carried out by falsely suspected servers. In both cases, liveness would get compromised. To overcome these problems, we exploit an in-

novative scheme for distributed transaction management, based on ad-hoc demarcation and concurrency control mechanisms, which we refer to as Multi-Instance-Precommit. With this scheme, we allow a falsely suspected server to proceed with transaction processing and pre-commit (i.e. no attempt to force the abort of its work is performed). Also, any server performing fail-over of a client request is granted access to the pre-image of any uncommitted data item updated by (falsely) suspected servers previously processing that same client request. In this way newly activated work in case of fail-over does not need to force the abort of previously activated one, and the two works do not block each other, which provides liveness guarantees for the end-to-end interaction. At the same time, the different (pre-committed) work instances are reconciled at commit time to maintain application safety (e.g. at-most-once semantic for request processing).

High Performance and QoS Oriented (Web-based) Distributed Systems Quality-of-Service (QoS) provisioning in the Internet has been a topic of active research in the last few years. However, due to both financial and technical reasons, the proposed solutions are not commonly employed in practice. As a consequence, in general settings, the Internet architecture is still mainly oriented to a best effort delivery model, which does not provide any guarantee neither on the message delivery latency, nor on the probability that a service residing at some host becomes temporarily unreachable due to network congestion. In this context, we have presented innovative, application level protocols tailored for Web transactional applications (e.g. e-Commerce applications), which attempt to reduce the impact of network congestion on the latency experienced by the end users. The intuition underlying our proposals is to exploit the intrinsic potential of parallelism commonly exhibited by Application Service Providers (ASPs) infrastructures, where the application access point is replicated over a large number of geographically distributed edge servers. At this purpose we allow privileged classes of users to concurrently contact multiple, replicated access points so to increase the probability to timely reach at least one of them and promptly activate the application business logic for the interaction with back-end database systems. We complete our proposals with efficient mechanisms that prevents multiple, undesired updates on the back-end databases and, at the same time, strongly limit the additional load on the ASP infrastructure due to the increased amount of requests from the privileged users.

The issue of QoS has been addressed also for the case of classical content delivery applications, for which it is becoming increasingly clear that different Web Sites may request different QoS levels to the same Content Delivery Networks (CDN), due to both their business targets and their financial availability. In this context, we have identified some resource management issues, and the related parameters, which affect the behavior of a CDN supporting different QoS levels for each of its Web sites, and have presented an analytical model for the evaluation of the provided QoS levels on the basis of both the specific assignment for the previous parameters and the available resources within the CDN. The model has also been employed to analyze the behavior of two different CDN configurations: (i) Exclusive Cache Node Assignment, where the cache nodes within the CDN are assigned to serve only requests for Web Sites that subscribe to a given QoS

class; (ii) Shared Cache Node Assignment, where each cache node can serve requests for multiple QoS classes. We have used real world data as input parameters of the model to test the behavior of the two different configurations and the tradeoffs of a configuration over the other.

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

In this context, a first objective was the definition of checkpointing mechanisms to reduce the overall checkpointing-recovery overhead. To this purpose, we have designed, implemented and tested a Checkpointing and Communication Library (CCL) for clusters based on Myrinet switches, which supports both fast message delivery and also CPU offloaded, i.e. DMA based, checkpointing functionalities.

We have also explored how uncertainty on the occurrence of the events within the simulated system space can be explored for increasing the flexibility in the synchronization scheme among simulation objects within the simulation system. We have exploited the uncertainty concept for both reducing the rollback overhead, in case of optimistic simulation, and more in general for reducing the forward computation cost for both parallel and serial simulation systems. Finally, we have studied the impact of uncertainty on the response rate in case of interactive distributed simulation, and more in general in case of simulation as a tool for decision makers in time constrained environments.

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 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, the HLA specification defines a suite of services, called Time-Management, to be offered by the RTI in support of synchronized execution among federates. However, this suite does not cover all the possible tasks associated with synchronization requirements. As a consequence, the application programmer is charged with the responsibility to circumvent such a lack and implement within the federate code modules to support those tasks. More in depth, according to the HLA specification, the RTI interface does not offer to the federate any access to services to checkpoint and/or recover its state. Hence, optimistic (i.e. rollback-based) synchronization, namely the most parallelism effective synchronization scheme also having the advantage of exhibiting performance relatively independent of the lookahead of the simulators within the federation, requires checkpointing and state recovery mechanisms to be built in the federate code. Unfortunately, the effort to implement these mechanisms inside the federate code discourages the adoption of this synchronization approach, at

the cost of reduced performance.

To provide a way to address such an issue, 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 Time-Management interface onto the optimistic one. In this way, TiMaC transparently supports optimistic execution for federates originally designed for the conservative approach, which is achieved without the need for developing any ad-hoc RTI system. TiMaC relies on a software architecture for transparent treatment of checkpointing/recovery of the federate state, namely Magic State Manager (MASM), we have also designed and developed, and implements a set of additional facilities required to support the whole tasks associated with the mapping of conservative onto optimistic Time-Management interfaces.

Then we have also investigated optimistic oriented intermediate approaches to synchronization, embedding the aggressiveness property of optimistic systems (hence simulation events can be speculatively executed without preventive assurance of their safety), but discarding risk (hence no message is ever sent out towards remote federates unless it is a committed message). To support such a kind of optimistic oriented synchronization scheme we have developed a middleware layer resulting as the evolution of TiMaC, which we refer to as Risk-Free-Speculator (RFS). This layer acts in a totally transparent manner to the overlying applications, and does not even require any modification of the underlying RTI. Also, RFS can provide advantages in applicative scenarios where the RTI publish/subscribe services might get overwhelmed by large volumes of messages eventually retracted due to rollback of some federates (e.g. simulations with large pub/sub groups). While intermediate synchronization approaches have been widely investigated in the context of traditional Parallel Discrete Event Simulation (PDES), to our knowledge this is the first attempt towards such an intermediate synchronization scheme in the context of the HLA standard.

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

We have also explored software diversity and active replication of application level simulation components, so to allow the whole HLA simulation system to take performance advantages from the "best instant responsiveness" among all the involved replicas. Within this scenario, our view of software diversity-based active replication entails the adoption of different third party libraries supporting typical simulation related tasks (for instance different libraries supporting calendar queues for the maintenance of the pending event set at the application level) or even the same library, but with different choices for the parameters determining its run time behavior, and then exploiting the timing of actions provided by the replica exhibiting the best run-time behavior for the specific synchronization conditions within the run, or even within specific phases of the run itself. This points out an important aspect related to our proposal. In particular, software

diversity as intended in our approach, does not necessarily mean having different implementations of a same simulation entity based on, e.g., different types of data structures and algorithms. It might simply mean employing different (or differently parameterized) third party libraries in support of simulation related, general purpose, application level tasks in order to originate diversity-based replicas. Hence our replication approach can provide real run-time advantages with no (or minimal) effort from teams of application programmers, who are not necessarily required to provide diversity-based implementations of a same application level simulation component. This means in practice following a kind of "Opportunistic N-Version Programming" such as the one followed in the context of replication in support of fault tolerance.

Beyond providing the framework for software diversity-based replication, we propose the design and implementation of an Active Replication Management Layer (ARML), which transparently supports software diversity-based replicas of a same HLA federate simulator, by showing them as a single logical entity. The implementation of ARML has been based on C technology and standard POSIX APIs. Hence it results portable across any kind of POSIX compliant operating system (e.g. UNIX systems). Also, such an implementation has been tailored for SMP and cluster based systems and, for being integrated with the well known Georgia Tech B-RTI package, even though the design principles underlying the implementation remain valid independently of the specific RTI to which replication handling facilities should be added.

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

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

System Modeling and Optimization Queueing networks is a typical methodology employed to model network behavior. Often network servers are modeled using the simplest models available, the $M/M/1$ queue, since the theory offers a nice closed form to express the output parameters of the queue. However workload characterization studies of complex systems, such as the GRID and the WWW, show that traffic behavior in such systems should be modeled by using more complex models of incoming traffic.

One of the most used models for incoming traffic, which is still similar to the Poisson Process, 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. The drawback of this model is that no closed form for its solution has been derived. Therefore, evaluating even the average response times of the queue is a computationally intensive task. Often the $MMPP/M/1$ queueing model is employed only by discrete event simulators, and not by analytical models, thus making it unfit for online decision-making. 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. Finally, the methodology is validated by comparing the behavior of the analytical approximation with analogous results obtained by a discrete event simulator simulating the same $MMPP/M/1$.

Journals

[1] A. Santoro and F. Quaglia, Transparent State Management for Optimistic Synchronization in the High Level Architecture, *SIMULATION: Transactions of The Society for Modeling and Simulation International*, vol.82, no.1, pp.5-20, 2006.

[2] A. Cosentino, M. Pedicini and F. Quaglia, Supporting Function Calls within PELCR, *Electronic Notes in Theoretical Computer Science*, vol.135, no.3, 107-117, 2006.

Conference proceedings

[3] P. Romano, F. Quaglia and B. Ciciani, A Simulation Study of the Effects of Multipath Approaches in e-Commerce Applications, *Proc. 20th IEEE International Parallel and Distributed Processing Symposium - DPDNS Workshop (IPDPS)*, Rhodes Island, Greece, IEEE Computer Society Press, April 2006.

[4] F. Quaglia, Enhancing the Performance of HLA-Based Simulation Systems via Software Diversity and Active Replication, *Proc. 20th IEEE International Parallel and Distributed Processing Symposium - APDCM Workshop (IPDPS)*, Rhodes Island, Greece, IEEE Computer Society Press, April 2006.

[5] F. Quaglia, A Middleware Level Active Replication Manager for High Performance HLA-based Simulations on SMP Systems, *Proc. 10th IEEE/ACM International Sym-*

posium on Distributed Simulation and Real Time Applications (DS-RT), Malaga, Spain, IEEE Computer Society Press, October 2006.

[6] A. Santoro and F. Quaglia, Transparent Optimistic Synchronization in HLA via a Time-Management Converter, *Proc. 20th ACM/IEEE/SCS Workshop on Principles of Advanced and Distributed Simulation (PADS)*, Singapore, IEEE Computer Society Press, May 2006.

[7] P. Romano, F. Quaglia and B. Ciciani, Design and Evaluation of a Parallel Edge Server Invocation Protocol for Transactional Applications over the Web , *Proc. 6th IEEE Symposium on Applications and the Internet (SAINT)*, Phoenix, Arizona, USA, IEEE Computer Society Press, January 2006.

[8] P. Romano and F. Quaglia, Providing e-Transaction Guarantees in Asynchronous Systems with Inaccurate Failure Detection, *Proc. 5th IEEE International Symposium on Network Computing and Applications (NCA)*, Cambridge, MA, USA, IEEE Computer Society Press, July 2006.

Submitted papers, technical reports and others

[9] F. Quaglia and P. Romano, Ensuring e-Transaction with Asynchronous and Uncoordinated Application Server Replicas. *IEEE Transactions on Parallel and Distributed Systems*, to appear.

[10] M. Pedicini and F. Quaglia, PELCR: Parallel Environment for Optimal Lambda-Calculus Reduction, *ACM Transactions on Computational Logic*, to appear.

[11] A. Santoro and F. Quaglia, Multiprogrammed Non-Blocking Checkpoints in Support of Optimistic Simulation on Myrinet Clusters. *Journal of Systems Architecture*, to appear.

[12] A. Santoro and R.M. Fujimoto, Off-Loading Data Distribution Management to Network Processors in HLA-Based Distributed Simulations, *IEEE Transactions on Parallel and Distributed Systems*, pending revision.

[13] P. Romano and F. Quaglia, Providing e-Transaction Guarantees with no Assumptions on the Accuracy of Failure Detection, submitted to an international journal.

[14] F. Quaglia, Spatial Uncertainty in Parallel Discrete Event Simulation: a Framework and an Application to Optimistic Synchronization, Technical Report.

[15] B. Ciciani, F. Quaglia, A. Santoro and P. Romano, Modeling of QoS-oriented Content Delivery Networks, Technical Report.

[16] P. Romano and F. Quaglia, Parallel Invocation Schemes for QoS-oriented Multi-tier Transactional Applications, Technical Report.

[17] F. Quaglia and A. Santoro, Transparent Risk-free Synchronization in the High-Level-Architecture Interoperability Standard, submitted to an international conference.

[18] B. Ciciani and A. Santoro, Approximating Output Parameters of $MMPP/M/1$ Queues, submitted to an international conference.

[19] F. Quaglia, Software Diversity-Based Active Replication as an Approach for Enhancing the Performance of Advanced Simulation Systems, *International Journal of Foundations of Computer Science*, special issue on selected papers from IPDPS/APDCM 2006.

3.1.8 Programming Languages and Methodologies

Our group hosts the research activities of a number of scientists, coming from university, Research and industrial bodies.

Group members Alberto BUDONI (DAU - Università "La Sapienza"), Gianna CIONI (IASI - CNR), Attilio COLAGROSSI (Presidenza del Consiglio dei Ministri), Luciano DE BONIS (Dip. SAVA, Università del Molise), Maria DE MARSICO (DI - Università "La Sapienza"), Carla LIMONGELLI (DIA - Università di Roma Tre), Andrea STERBINI (DI - Università "La Sapienza"), Marco TEMPERINI (DIS - Università "La Sapienza").

We work on

1. the development of methodological and applicative aspects of the *Open and Distance Learning* model.
2. the principles of object-oriented programming languages and their applications in distributed (object-oriented) programming;
3. application of ICT to collaborative working and participation planning.

Open and Distance Learning We work on the configuration of courses, tailored on the learning needs of the individual learner: A basic mathematical logic and automated reasoning approach has been extended with the definition and use of *learning objective templates* in order to allow for a formal definition of curricula, which are presently expressable only through informal description of learning objectives [5].

Working in the ODL area, we participate and have participated in EU and multinational research initiatives, which led recently to monographs such as [2, 3, 4]:

- *EuroCompetence* (A university - workplace model for developing knowledge for European Collaboration), Socrates Project Number : 56544-CP-1-98-1-NO-ODL-ODL.
- *CIOC* (Competence Development in Internationally Oriented Companies), funded by the NFU (Norwegian State Institution for Distance Education, project n. 18, 2000-2002), with participants from TEI Thessaloniki from Greece, DIS - La Sapienza from Italy, NITOL, TISIP Trondheim and Siemens Metering from Norway, Siemens from Switzerland, University of Greenwich from United Kingdom.

- *mENU* (model for a European Networked University), elearning project n.2002–0510/001–001–EDU–ELEARN, `http://www.hsh.no/menu/`.

- *QUIS* (QUality, Interoperability and Standards in e-learning), Agreement n. 2004 – 3538 /001 – 001 ELE–ELEB14 `http://www.tisip.no/quis/`, [2, 3, 4]).

Distributed object-oriented programming Being interested in inheritance in object-oriented programming, we have started an activity on the application of inheritance in distributed object-oriented programming environments. This activity has led to the definition of a scheme for supporting the so-called *remote inheritance*, that is the use of the inheritance mechanism for the definition and use of class hierarchies distributed through a set of computing sites. A class (hierarchy) is defined in a server and many clients can use it in their local programming; when a class is updated, each client will eventually reload its code, in order to use the updated code. We analyzed the use of RMIClassLoader for dynamic class loading, obtaining an initial programming framework. We have then extended the framework, such that a distributed database is used to manage updates and classloadings; in this extension Aglets travel the network and are executed on each client to check the needs for actual updates. Presently we are analyzing other technologies, such as the use of JavaSpace Server to support the exchange and update of remotely maintained classes into local applications, and the use of Jini, in different flavors, basically to obtain the same result. The activity on this subject is conducted so far through development of *Laurea* thesis.

Support to collaborative working and participation planning We have started an interdisciplinary activity, in collaboration with colleagues from the area of Environment Engineering ([1]). The activity has been focused on the design and development of a prototypal web application supporting the discussion about plans (*projects*). The website provides basically 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.

Conference Proceedings

[1] A. Budoni, L. De Bonis, M. Temperini. Rethinking PPGIS in the perspective of free and open content systems. *Proc. of the25TH Urban Data Management symposium (UDMS 2006)*, May 15-17, 2006, Ålborg, Denmark (2006)

Submitted papers, technical reports and others

[2] F. Di Domenico, A. Sterbini, M. Temperini. Analysis of commercial and experimental e-learning systems. *Project QUIS: QUality, Interoperability and Standards in e-learning*, Agreement n. 2004 – 3538 /001 – 001 ELE–ELEB14. The TISIP Research Foundation, Trondheim, (2nd ed.) 2006, ISBN 82-8055-017-8

[3] A.M. Bianco, M. De Marsico, M. Temperini. Standards for e-learning. *Project QUIS: QUality, Interoperability and Standards in e-learning*, Agreement n. 2004 – 3538 /001 – 001 ELE–ELEB14. The TISIP Research Foundation, Trondheim, (2nd ed.) 2006, ISBN 82-8055-018-6

[4] M. De Marsico, F. Hjeltnes, A. Staupe, M. Temperini. Data Specification for the Definition of a Topic Map on Standards in E-learning. *Project QUIS: QUality, Interoperability and Standards in e-learning*, Agreement n. 2004 – 3538 /001 – 001 ELE–ELEB14. The TISIP Research Foundation, Trondheim, 2006, ISBN 82-8055-024-6

[5] G. Fernandez, A. Sterbini, M. Temperini. On the Specification of Learning Objectives for Course Configuration Accepted at 6th Int. Conference on Web-Based Education (WBE 2007), Mar 14-16, 2007, Chamonix, France (2007)

3.2 Systems science

3.2.1 Biomedical Systems

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

The group consists of people from several institutions. In particular from IASI-CNR, Roma; Istituto di Clinica Medica-Policlinico A.Gemelli, Università Cattolica del Sacro Cuore, Roma; Istituto di Fisiologia Umana, Università di Roma "La Sapienza", Roma; and IRCCS S. Lucia, Roma.

Group members Alessandro BERTUZZI and Alberto GANDOLFI (IASI-CNR); Geltrude MINGRONE (Istituto di Clinica Medica-Policlinico A. Gemelli Università Cattolica del Sacro Cuore-Roma); FabioBABILONI, Claudio BABILONI, Filippo CARDUCCI (Istituto di Fisiologia Umana, Università di Roma "La Sapienza"), Febo CINCOTTI (IRCCS S. Lucia, Roma), Serenella SALINARI, LauraASTOLFI (Dipartimento di Informatica e Sistemistica).

Analysis and Modelling of Metabolic Systems The interest was mainly focused on: i) the analysis of a new energy substrate (dodecanedioic acid C12) and ii) the analysis of the glucose and lipid metabolism and their interaction in healthy and obese subjects.
i) Metabolically healthy skeletal muscle possesses the ability to switch easily between glucose and fat oxidation in response to homeostatic signals. In type 2 diabetes mellitus and obesity, the skeletal muscle shows a great reduction in this metabolic flexibility. A substrate like dodecanedioic acid (C12), able to increase skeletal muscle glycogen stores, might both postpone the fatigue and increase fatty acid utilization, since it does not affect insulin secretion. To test this hypothesis, the effect of an oral C12 load was compared to a glucose or water load during prolonged, moderate-intensity, physical exercise in healthy volunteers and in type 2 diabetic subjects [1]. Experimental data of C12 disposition was analysed by a mathematical model. The results of this study confirmed the possibility of using C12 as a suitable energy substrate during exercise, since it reduces muscle fatigue, is rapidly oxidized and does not stimulate insulin secretion, which implies that lipolysis is not inhibited as reported after glucose ingestion.
ii) We elaborated a new mathematical model that describes the dual control of insulin release by glucose and FFA [17]. Based on this model, data of multiple-meal experiments were analyzed. Parameters of β-cell function were estimated in control subjects as compared to obese patients before and after diet. The model is based on the experimental evidence that a source of fatty acids (FAs) either exogenous or endogenous is necessary to support normal insulin secretion. Therefore, FAs co-modulate the glucose-induced pancreatic insulin secretion. Model parameters, obtained by fitting the individual experimental data of plasma C-peptide concentration, gave an estimated ISR comparable to that obtained by the well assessed deconvolution method. This model of nutrient-stimulated insulin secretion is the first attempt to represent in a simple way a complex molecular mechanism of regulation of insulin secretion in the β-cell and explains, at least

in part, the 'potentiation factor' used in previous models to account for other control factors different from glucose. In the same context, a mathematical model representing the dynamics of intracellular insulin granules in β -cells was also proposed [18]. The model provides an interpretation of the roles of the triggering and amplifying pathways of glucose-stimulated insulin secretion. Values of most of the model parameters were inferred from available experimental data. The numerical simulations, relative to a variety of experimental conditions, agree with published experimental data.

Analysis of Brain Potential related to Motor Control The research activity involved problems connected with i) the estimation of the effective and functional human cortical connectivity; ii) the analysis of the brain potential modifications in patients affected by the Alzheimer disease (AD).
i) The concept of brain connectivity plays today a central role in the neuroscience. While functional connectivity is defined as the temporal coherence between the activities of different brain areas, the effective connectivity is defined as the simplest brain circuit that would produce the same temporal relationship as observed experimentally between cortical sites. In the last year the aim of the work was devoted to characterize quantitatively the performance of a body of techniques in the frequency domain for the estimation of cortical connectivity from high-resolution EEG recordings in different operative conditions commonly encountered in practice [5], [6], [7], [10], [11], [12], [13], [14]. Connectivity pattern estimators investigated are the Directed Transfer Function (DTF), its modification known as direct DTF (dDTF) and the Partial Directed Coherence (PDC) [2]. Predefined pattern of cortical connectivity were simulated and then retrieved by the application of the three methods. Signal-to-Noise ratio (SNR) and length of EEG epochs were studied as factors affecting the reconstruction of the imposed connectivity pattern. The error functions were analysed with the Analysis of Variance (ANOVA). The whole methodology was then applied to high-resolution EEG data recorded during the well-known Stroop paradigm [15]. The results of the analysis confirmed that functional connectivity patterns of cortical activity can be effectively estimated by combining high-resolution EEG techniques [8], [9], [16], linear inverse estimation of the cortical activity and frequency domain multivariate methods as DTF, dDTF and PDC [19], [20].
ii) The study was aimed to test the hypothesis that differences in the responses of patients with mild Alzheimer's disease (AD) [3] to acetylcholinesterase inhibitors (AChEI) such as Donepezil may be due to different functional features of the central nervous system [4]. To this purpose the cortical electroencephalographic rhythms were used. Resting eyes-closed EEG data were recorded in mild AD patients before and 1 year after the therapy. Cortical sources were studied with low resolution brain electromagnetic topography (LORETA). The analysis showed that, before treatment, the sources of delta, alpha1 and alpha2 rhythms are greater in non-responder subjects and that, after the treatment, a lesser magnitude reduction of occipital and temporal alpha1 sources characterized responders. These results confirmed that responder and non responder subjects have different cortical rhythms and that Donepezil could act by reactivating existing yet functionally silent cortical synapses in responders, restoring temporal and occipital rhythms.

Journals

[1] Salinari S., Bertuzzi A, Gandolfi A, Greco A.V, Scarfone A, Manco M, Mingrone G. Dodecanedioic acid overcomes metabolic inflexibility in type 2 diabetic subjects. *American Journal of Physiology-Endocrinology and Metabolism*, vol.291, pp. 1051-1058, 2006.

[2] Astolfi L, Cincotti F, Mattia D, Marciani MG, Baccala LA, De Vico Fallani F, Salinari S., Usino M, Zavaglia M, Babiloni F. Assessing cortical functional connectivity by partial directed coherence: simulations and application to real data. *IEEE Transactions on Biomedical Engineering*, vol.53(9), pp. 1802-1812, 2006.

[3] Babiloni C, Binetti G, Cassetta E, Dal Forno G, Del Percio C, Ferreri F, Ferri R, Frisoni G, Lanuzza B, Miniussi C, Moretti D.V, Nobili F, Rodriguez G, Romani G.L, Salinari S, and Rossini P.M Sources of cortical rhythms in subjects with mild cognitive impairment: a multi-centric study. *Clinical Neurophysiology*, vol. 117(2), pp. 252-268, 2006.

[4] Babiloni C, Cassetta E, Dal Forno G, Del Percio C, Ferreri F, Ferri R, Lanuzza B, Miniussi C, Moretti D.V, Nobili F, Pascual-Marqui R.D, Rodriguez G, Romani G.L, Salinari S, Zanetti O, and Rossini P.M. Donepezil effects on sources of cortical rhythms in mild Alzheimers disease: responders vs. non responders. *Neuroimage*, vol. 31(4), pp.1650-1665, 2006.

[5] Babiloni C, Cassetta E, Dal Forno G, Del Percio C, Ferreri F, Ferri R, Lanuzza B, Miniussi C, Moretti D.V, Nobili F, Pascual-Marqui R.D, Rodriguez G, Romani G.L, Salinari S., Zanetti O, and Rossini P.M. Estimation of the cortical connectivity patterns during the intention of limb movements. *IEEE Engineering in Medicine and Biology Magazine*, vol. 25(4), pp.32-38, 2006.

[6] L. Astolfi, F. Cincotti, D. Mattia, M.G. Marciani, L. Baccala, F. De Vico Fallani, S. Salinari, M. Ursino, M. Zavaglia, L. Ding, J.C. Edgar, G.A Miller, B. He and F. Babiloni A comparison of different cortical connectivity estimators for high resolution EEG recordings. *Human Brain Mapping*, vol. 28, pp.143-157, 2006.

[7] L. Astolfi, F. Cincotti, D. Mattia, M.G. Marciani, F. De Vico Fallani, S.Salinari and F. Babiloni. Stima della connettivit cerebrale mediante EEG ad alta risoluzione spaziale. *Automazione e Strumentazione*, vol. 11, pp. 80-86, 2006.

Articles in books

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

Conference proceedings

[9] Astolfi, L.; Cincotti, F.; Mattia, D.; Babiloni, F.; Grazia Marciani, M.; De Vico Fallani, F.; Mattiocco, M.; Miwakeichi, F.; Yamaguchi, Y.; Martinez, P.; Salinari, S.; Tocci, A.; Bakardjian, H.; Vialatte, F.B.; Cichocki, A.; Removal of ocular artifacts for high resolution EEG studies: a simulation study *Engineering in Medicine and Biology Society, 2006. EMBS '06. 28th Annual International Conference of the IEEE* Aug. 2006 Page(s):976 - 979

[10] De Vico Fallani, F.; Astolfi, L.; Cincotti, F.; Mattia, D.; Grazia Marciani, M.; Salinari, S.; Zamora Lopez, G.; Kurths, J.; Changson Zhou; Shangkai Gao; Colosimo, A.; Babiloni, F.; Brain Connectivity Structure in Spinal Cord Injured: Evaluation by Graph Analysis. *Engineering in Medicine and Biology Society, 2006. EMBS '06. 28th Annual International Conference of the IEEE*Aug. 2006 Page(s):988 - 991

[11] Mattiocco, M.; Babiloni, F.; Mattia, D.; Bufalari, S.; Sergio, S.; Salinari, S.; Marciani, M.G.; Cincotti, F.; Neuroelectrical source imaging of mu rhythm control for BCI applications *Engineering in Medicine and Biology Society, 2006. EMBS '06. 28th Annual International Conference of the IEEE*Aug. 2006 Aug. 2006 Page(s):980 - 983

[12] Laura Astolfi, Fabrizio De Vico Fallani, Febo Cincotti, Donatella Mattia, Maria Grazia Marciani, Serenella Salinari, Shangkai Gao, Wei Wu, and Fabio Babiloni Assessing time-varying causality between cortical areas of the brain by adaptive multivariate estimators *The 17th Meeting of the International Society for Brain Electromagnetic Topography* Chieti, Italy, September 27-30, 2006.

[13] Laura Astolfi, Fabrizio De Vico Fallani, Febo Cincotti, Donatella Mattia, Maria Grazia Marciani, Luigi Bianchi, Marco Mattiocco, Serenella Salinari, and Fabio Babiloni Hypermethods for EEG hyperscannings *The 17th Meeting of the International Society for Brain Electromagnetic Topography* Chieti, Italy, September 27-30, 2006.

[14] Fabrizio De Vico Fallani, Fabio Babiloni, Febo Cincotti, Marco Mattiocco, Donatella Mattia, Maria Grazia Marciani, Serenella Salinari, Shangkai Gao , Dan Zhang , Ding L., Edgar J. Miller B. , He B. Alfredo Colosimo and Laura Astolfi Cortical causality patterns during the execution of cognitive and motor tasks in normal and disabled subjects by using high resolution EEG and graph theory *The 17th Meeting of the International Society for Brain Electromagnetic Topography* Chieti, Italy, September 27-30, 2006.

[15] Fabio Babiloni, Fabrizio De Vico Fallani, Febo Cincotti, Donatella Mattia, Maria Grazia Marciani, Serenella Salinari, Alfredo Colosimo, Lei Ding, J Edgar, B Miller, Bin He, Laura Astolfi Cortical causality patterns during the execution of a Stroop task in normal subjects by using multimodal integration of high resolution EEG and fMRI recordings *OHBM* Florence, Italy, 11-15 June 2006

[16] F. Babiloni, F. Cincotti, D. Mattia, M.G. Marciani, F. De Vico Fallani, S. Bufalari, S. Salinari, L. Astolfi Neural basis for the brain responses to the marketing messages as revealed by high resolution EEG *OHBM* Florence, Italy, 11-15 June 2006

Submitted papers, technical reports and others

[17] S. Salinari, A. Bertuzzi, M. Manco, G. Mingrone NEFA-Glucose co-modulation model of beta-cell insulin secretion in 24-hour multiple meal test *American Journal of physiology E&M* , submitted.

[18] A. Bertuzzi, S. Salinari, G. Mingrone Insulin granule trafficking in b-cells: mathematical model of glucose-induced insulin secretion *American Journal of physiology E&M*, submitted.

[19] L. Astolfi, F. Cincotti, D. Mattia, F. De Vico Fallani, A. Colosimo, S. Salinari, M. G. Marciani, W. Hesse, H. Witte, M.Ursino, M.Zavaglia, and F. Babiloni Tracking the time-varying cortical connectivity patterns by adaptive multivariate estimators *IEEE Transaction on Biomedical Engineering*, submitted.

[20] L. Astolfi, F. De Vico Fallani, F. Cincotti, D. Mattia, M.G. Marciani, S. Bufalari, S. Salinari, Alfredo Colosimo, S. Gao, L. Ding, J.C. Edgar, G.A. Miller, B. He and F. Babiloni Functional connectivity estimates by multimodal integration of eeg and fmri data: application to a visual stroop task . *Human Brain Mapping*, submitted.

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.

National and international research projects include: PRIN “Sensori, attuatori e sistemi per il controllo di movimentazione basati su I.P.M.C.”, GALILEO project, “Complex dynamical systems: classification and case studies”.

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

Group members Alessandro DE CARLI, Claudio GORI GIORGI, Salvatore MONACO, Claudia CALIFANO, Paolo DI GIAMBERARDINO, Roberto RONCHINI, Andrea USAI (PhD student), Simone GABRIELE (PhD student).

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.

More recent developments deal with virtual reality simulation in particular in the area of manufactory plants, a new approach to the motion control design of a multi axes

motion has been proposed and applied [6, 7]. The improvement obtained, making use of the non-proprietary language UML, was considered very useful from the plant integrator.

Discrete-time systems The contributions in this area are concerned with exact and approximate feedback linearization and observer design with linear error dynamics. In [3], the controller normal form approach has been applied to solve the problem if approximated feedback linearization; while in [22, 23, 19] the normal forms approach has been applied to solve the nonlinear observer problem. In [16] the formalism of chronological calculus for studying time-varying differential equations has been extended to the analysis of discrete-time dynamics. In [25], the equivalence under coordinates change and output transformation to observer canonical forms is analyzed for discrete time systems with two output; the general case is addressed in [26].

Digital and switching control A formalization of necessary and sufficient conditions for achieving an exact sampled model, together with some constructive results, have been given in [8]. On theses bases a new approach to the design has been proposed in [4] and [14] to solve control problems under visual feedback. Several contributions deal with the investigation of the properties of the sampled model to get new insights and ideas for the design of digital control schemes [13, 11, 18, 12, 17, 20, 24].

Sensors and Measurements It is well known that measurements represent the very critical part of any control problem, and a lot of work has been done for improving all the components and processes involved, from sensors to transmission, from filtering to manipulation/elaboration, from data storage to data presentation. Moreover, in several problems the acquisition of measurements represents the most important part of high level control schemes, like those employed in monitoring or surveillance. In these schemes, distributed sensors systems and networks are assuming a more and more important role. The research activities here described want to conjugate these emerging sensors applications with classical mobile robotics to produce intelligent dynamic sensor networks. 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 it 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 devices, computation algorithm and actuation systems. In [9] and [1] a particular ultrasonic sensor for parallel simultaneous distance measurements is studied and proposed. In [10] and [2] an embedded solution for the position and/or velocity feedback control of actuators based on electrical motors (no matter what kind of motor is actually used – DC, servo, step motors) is proposed. The control scheme employs any one of the most common sensors, such as potentiometers, encoders, etc. The use of a camera mounted on a mobile robot for autonomous motion and environment analysis is presented in [5].

Journals

[1] A. Fabrucci, A. Usai and P. Di Giamberardino. Noise and Ultrasonic Sensors: Troubles or Advantages?, *WSEAS Transactions on Signal Processing*, 5(2), pp. 626–634, 2006.

[2] C. Massacci, A. Usai and P. Di Giamberardino. A Radio Connected Intelligent Motor Control Board for Mobile Robotic Applications, *WSEAS Transactions on Circuits and Systems*, 8(5), pp.1259-1265, 2009.

[3] S. Monaco and D. Normand-Cyrot. Normal Forms and Approximated Feedback Linearization in Discrete Time, *Systems & Control Letters*, v. 55, n.1, pp. 71-80, 2006.

[4] A. Usai and P. Di Giamberardino. A Multirate Digital Controller for Nonholonomic Mobile Robot Pose Regulation via Visual Feedback, *WSEAS Transactions on Systems*, 5(5), pp. 1129–1136, 2006.

[5] A. Usai and P. Di Giamberardino. Autonomous Robot Motion in an Unknown Environment by Local 3D Elevation Map Construction, *Integrated Computer-Aided Engineering*, Vol. 3, No. 13, 2006.

Conference proceedings

[6] A. De Carli and O. Marinelli. Motion Control Design of a Manufactory Plant by Dedicated Software. In *Proceedings 9th IEEE International Workshop on Advanced Motion Control*, Istanbul, March 2006.

[7] A. De Carli and M. Zanchiello. Modelling and Simulation of Manufacturing Systems using ProModel Software. In *Proceedings International Congress ANIPLA on Emerging Techologies in Automation*, Roma, Novembre 2006.

[8] P. Di Giamberardino, S. Monaco and D. Normand-Cyrot. On Equivalence and Feedback Equivalence to Finitely Computable Sampled Models, In *Proceedings 45th IEEE Conf. on Decision and Control*, San Diego (CA), USA, pp. 5869-74, Dec. 2006.

[9] A. Fabrucci, A. Usai and P. Di Giamberardino. A Parallel Ultrasonic Sensors System: Prototypal Realization and Validation Tests, In *Proceedings 5th WSEAS Int. Conf. on Signal Processing*, Istanbul, Turkey, May 2006.

[10] C. Massacci, A. Usai and P. Di Giamberardino. An Embedded Approach for Motor Control Boards Design in Mobile Robotics Applications, *in Proceedings 10th WSEAS Int. Conf. on Circuits*, Athens, Greece, July 2006.

[11] S. Monaco and D. Normand-Cyrot. On nonlinear sampling inversion, *in Proceedings 44-th Cont. & Dec. Conf.*, San Diego, pp. 3718-23, Dec. 2006.

[12] S. Monaco and D. Normand-Cyrot. Input-state matching under digital control, *in Proceedings 44-th Cont. & Dec. Conf.*, San Diego, pp. 1806-11, Dec. 2006.

[13] S. Monaco and D. Normand-Cyrot. Some comments about normal forms under sampling, *in Proccedings Amer. Cont. Conf.*, Minneapolis, June 2006.

[14] A. Usai and P. Di Giamberardino. Nonholonomic mobile robot visual servoing: a multirate digital approach, *in Proceedings 8th WSEAS Int. Conf. on Automatic Control, Modeling and Simulation*, pp. 134-139, Prague, Czech Republic, Mar. 2006.

Submitted papers, technical reports and others

[15] A. De Carli. La realtà virtuale a supporto della progettazione di apparati controllati. Editoriale per la rivista *Automazione e strumentazione*, Maggio 2006.

[16] S. Monaco, D. Normand-Cyrot and C. Califano. From chronological calculus to exponential representations of continuous-time and discrete-time dynamics: a Lie-algebraic approach. Accepted for publication in *IEEE Transactions on Automatic Control*, 2006.

[17] S. Monaco and D. Normand-Cyrot. Advanced Tools for Nonlinear Sampled-Data Systems' Analysis and Control. Accepted for publication in the *European Journal of Control*, 2006.

[18] S. Monaco and D. Normand-Cyrot. On digital controller inversion. Accepted at *SICPRO*, Mosca, gennaio 2007.

[19] J.P. Barbot, S. Monaco and D. Normand-Cyrot. On the observer for differential-difference representations of discrete-time systems. Accepted at the *European Control Conference '07*, 2006.

[20] S. Monaco and D. Normand-Cyrot Linearization by output injection under sampling. Accepted at the *European Control Conference '07*, 2006.

[21] S. Battilotti and C. Califano. A geometric approach to dynamic feedback linearization. Submitted for publication, 2006.

[22] S. Monaco and D. Normand-Cyrot. Controller and observer normal forms in discrete-time. Submitted for publication, 2006.

[23] S. Monaco and D. Normand-Cyrot. On observer normal forms in discrete time. Submitted for publication, 2006.

[24] S. Monaco and D. Normand-Cyrot. On input-state matching under multirate digital control. Submitted for publication, 2006.

[25] C. Califano, S. Monaco and D. Normand-Cyrot. State estimation for two output systems in Discrete Time. Submitted to *Nolcos*, 2006.

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

3.2.3 Identification and Optimal Control

The scientific interest of the group lies in two main areas: modeling, identification and filtering for discontinuous 2D signals and dynamical systems; deterministic and stochastic optimal control.
In the first area the problems of edges detection and motion extimation from sequence of blurred and noisy images have been considered; also the problem of state estimation in respiratory gas exchange models has been studied.
In the second area the application of filtering and optimization tecniques to traffic control in a wireless communication network was considered (part of this latter research was developed in the framework of the IMAGES, EQoS and WEIRD projects belonging to the Information Society and Technology programme, sponsored by the 6th Framework EU programme); moreover a global population-based optimization procedure was investigated.

Group members Carlo BRUNI, Francesco DELLI PRISCOLI, Claudia FERRONE, Giorgio KOCH, Matteo LUCCHETTI, Ilaria MARCHETTI, Caterina SCOGLIO.

Edge detection and motion estimation 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 by no mean trivial, since measured images are usually degraded by blurring effect and additive noise.
The problem of analyzing degraded images time sequences has been considered, assuming that the represented objects can nonrigidly move and in particular that motion and deformation law is described by an affine time dependent transformation on R^2. Initially, the possibility of recovering the image content has been studied, assuming full information about the motion law. In this case the estimation problem is linear with respect to the grey levels and the high dimensionality drawback has been solved by a suitable preprocessing procedure.
As a second issue the problem of motion estimation has been considered: this is a nonlinear problem and therfore suitable approximate filtering techniques are requested. In particular gaussian approximations by linearization methods have been considered. Particular attention has been dedicated to the selection of the pixels to be processed, according to their informative content.

Modeling and Filtering of Biomedical Systems The gas exchange mechanism in the respiratory system has been described by a nonlinear dynamical model. The problem of estimating the state variables, of medical interest, has been solved by approximate (extended Kalman) filters. Analysis of the obtained approximations has been performed, with application to simulated and real data; also comparisons with the results given by classical biomedical approaches to the above problem have been performed. Useful conclusions have been provided about the choice of the model and the related filtering procedure with reference to the respiratory system volume and the measurement instrumentation quality level.

Modeling, filtering and optimal control of communication networks The problem of congestion and admission control from a base station in a wireless communication network has been considered. As a first step the problem of modeling the network as a stochastic dynamical system has been tackled, with the aim of formulating an optimal control problem, transforming the quality of service requirements into suitable analytic constraints. A simplified formulation of the problem has been considered, characterized by the decomposition of the time control interval into a sequence of subintervals, thus dealing with a sequence of easy optimization problems. An on line suboptimal solution for the initial problem can be given following this approach.
Also an innovative approach to the connection admission control problem has been studied, which again is characterized by a predictive optimal formulation: it turns out to be technology independent and decoupled from the other resource management procedures (with which it indeed cooperates).
Also the problem of optimal filtering and forecasting in traffic estimation for bandwidth brokers has been studied.

The possibility of exploiting the above filtering and forecasting procedures has also been considered in order to formulate and solve an optimal dynamical band allocation problem, with the specific aim of minimizing the number of bandwith renegotiations.

Population-Based Global Optimization Methods A population-based global optimization method has been proposed which is characterized by a suitable births control strategy, aimed to intensify the search in the most promising subregions of the admissible set. This approach can be of interest in optimal control problem of complex dynamical systems, possibly in the presence of time changes (continuous optimization)or of unpredictable and unmodeled disturbances (stochastic optimization).

Journals

[1] Bruni C., Iacoviello D., Koch G., Lucchetti M., Filtering Images Sequences from a Moving Object and the Edge Detection Problem, *Computer and Mathematics with Applications*, **51**, 3/4, 2006.

[2] Brandes A., Bruni C., Granato L., Estimation of Respiratory Gas Exchange: a Comparative Study of Linear and Nonlinear Model-Based Estimation Techniques, *IEEE Transaction on Biomedical Engineering*, **53**, 7, July 2006.

[3] Bruni C., Delli Priscoli F., Koch G., Marchetti I., An Optimal Approach to the Connection Admission Control Problem, *International Journal of Control*, **79**, 10, October 2006.

[4] Bruni C., Delli Priscoli F., Koch G., Marchetti I., An Innovative Approach to the Formulation of Connection Admission Control Problem, *Transaction on Engineering, Computing and Technology*, **18**, December 2006.

[5] Anjali T., Bruni C., Iacoviello D., Scoglio C., Dynamic Bandwidth Reservation for Label Swithched Paths: an On-Line Predictive Approach, *Computer Communications*, **29**, 16, October 2006.

[6] Bruni C., Ferrone C., Lucchetti M., Global Optimization for Possibly Time Dependent Cost Functions by a Population Set Based Algorithm with Births Control, *Computer and Mathematics with Applications*, **52**, 6/7, 2006.

Conference proceedings

[7] Bruni C., Delli Priscoli F., Koch G., Marchetti I., An Innovative Approach to the Formulation of Connection Admission Control Problem, *Proc. XVIII International Conference on Computer and Information Science and Engineering*, Vienna, December 2006.

[8] Bruni C., Delli Priscoli F., Koch G., Marchetti I., Connection Admission Control in Cellular Networks: a Discrete Time Optimal Solution, *Proc. IEEE Infocom 2006*, Barcellona, April 2006.

Ph.D. thesis

[9] Ferrone C., *Motion Estimation from a Sequence of Degraded Images.* Ph.D. Thesis, Sapienza Università di Roma, 2006.

[10] Marchetti I., *Connection Admission Control Problem fo Heterogeneous Networks: An optimal Solution.* Ph.D. Thesis, Sapienza Università di Roma, 2006.

Submitted papers, technical reports and others

[11] Bruni C., Delli Priscoli F., Koch G., Marchetti I., Discrete Time Optimal Solution to the Connection Admission Control Problem, *International Journal of Information Technology*, submitted.

[12] Bruni C., Ferrone C., Koch G., Lucchetti M., Non Rigid Motion Estimation from a Sequence of Degraded Images, *Math Models and Methods in Applied Sciences*, submitted.

[13] Bruni C., Ferrone C., Koch G., Lucchetti M., Estimation Problems from a Sequence of Degraded Images, *4th International Conference on Cybernetics and Information Technologies, Systems and Applications*, Orlando (Florida), July 2007, submitted.

[14] Bruni C., Delli Priscoli F., Koch G., Marchetti I., The Connection Admission Problem in Internet Networks: an Optimal Control Approach, European Control Conference 2007, Kos, Greece, July 2-5, 2207. To appear.

3.2.4 Nonlinear Systems

The research group in Nonlinear Systems is involved in the development of the following topics: control under communication constraints, nonlinear regulation, resource management in wireless systems, stabilization of nonlinear systems.

Group members Stefano BATTILOTTI, Marco CASTRUCCI, Fabio CELANI, Francesco DELLI PRISCOLI, Claudio DE PERSIS, Tiziano INZERILLI, Alessandro DI GIORGIO, Alberto ISIDORI, Ilaria MARCHETTI, Andrea MERCURIO, Silvano MIGNANTI, Antonio PIETRABISSA, Gianfranco SANTORO, Vincenzo SURACI.

Control under communication constraints Networked control systems are required to achieve control goals in spite of the deleterious effects of the communication channel. The addition of devices called encoders to process information has proven very effective. For instance, under a robustness requirement weaker than input-to-state stability, namely *integral* input-to-state stability, and full state measurements, an encoder exists and stabilizability holds [7]. When only output measurements are available for feedback, the signal may not be sufficiently informative to counteract the effect of the channel. To enrich the information, a possibility is to embed an asymptotic observer into the encoder, and then transmit as feedback variable the internal state of the embedded observer. This is pursued in [6], where systems which are uniformly observable are considered, and the existence of a stabilizing scheme is related to an appropriate choice of the observer gain and the channel bandwidth. In [12], encoders have been employed to solve the output regulation problem when the reference signal is generated at a remote location.
Although encoders allow one to effectively counteract the limitations due to the communication channel, they may require a large amount of computational capability. When this is not available, more elementary encoding schemes must be adopted. A family of these schemes has been presented in [17], based on logarithmic quantizers. These schemes can be implemented through an hysteresis-like mechanism which prevent undesired effects such as chattering. An unabridged version of the results is available in [28].
All the contributions above consider single channel scenarios. However, in many networked systems resources are distributed. In [18, 29], we examine a case study in an industrial problem of ventilation and air conditioning. The problem consists of guaranteeing prescribed indoor climate conditions in a cascade connection of an arbitrarily large number of communicating zones, in which air masses are exchanged to redirect warm air from hot zones (which need to be cooled down) to cold zones (which need to be heated up), and to draw as much fresh air as possible to hot zones, relying on the ventilation capacity of neighboring "collaborative" zones. The controller of each zone must be designed so as to achieve the prescribed climate condition, while fulfilling the constraints imposed by the neighboring zones due to their willingness to cooperate or not in the air exchange and the conservation of flow, and despite the action of unknown disturbances. We devise control laws which produce *hybrid* closed-loop systems, depend on local feedback information, take on values in a finite discrete set, and cooperate with neighbor controllers to achieve different compatible control objectives, while avoiding conflicts.
In [13], a globally stabilizing finite-horizon MPC has been suggested for neutrally stable continuous-time systems using a non-quadratic terminal cost which consists of cubic as well as quadratic functions of the state.

Nonlinear regulation Research in this area had been addressed to various problems of stabilization and asymptotic regulation.

The work in [9] and [10] shows how the theory of adaptive observers can be effectively used in the design internal models for nonlinear output regulation. The main result obtained in this way is a new method for the synthesis of adaptive internal models which substantially enhances the existing theory of adaptive output regulation, by allowing nonlinear internal models and more general classes of controlled plants.

The paper [32] addresses the problem of existence of an (output) feedback law to the purposes of asymptotically steering to zero a given controlled variable, while keeping all state variables bounded, for any initial condition in a given compact set. The problem can be viewed as an extension of the classical problem of semi-globally stabilizing the trajectories of a controlled system to a compact set. The problem also encompasses a version of the classical problem of output regulation. Assuming only the existence of a feedback law that keeps the trajectories of the zero dynamics of the controlled plant bounded, it is shown that there exists a controller solving the problem at hand. The paper is deliberately focused on theoretical results regarding the existence of such controller. Practical aspects involving the design and the implementation of the controller are left to a forthcoming work.

In paper [25] the techniques developed in [32] have been applied to the problem of estimating amplitude, phase and frequency of a pure sinusoid. It is shown how the estimation can be carried out by processing, through a static nonlinear function, the state of an Hurwitz system of suitable dimension. Simulation results are also presented showing the effectiveness of the method also in presence of high frequency noise superimposed to the estimated sinusoid.

The goal of the work in [33] is to propose a unique vision able to frame a number of results recently proposed in the literature to tackle problems of output regulation for nonlinear systems. This is achieved by introducing the so-called asymptotic internal model property as the crucial property which, if fulfilled, leads to the design of the regulator for a fairly general class of nonlinear systems satisfying a proper minimum-phase condition. It is shown that recent frameworks based upon the use of nonlinear high-gain and adaptive observer techniques for the regulator design can be cast in this setting. A recently proposed technique for output regulation without immersion is also framed in these terms.

In papers [20] and [21], we discuss the problem of global robust output regulation for a class of nonlinear systems. With respect to earlier results on this problem for the same class of systems, the major advancement is the assumption that a nonlinear differential equation models the class of all inputs needed to secure perfect tracking, as opposed to the earlier results in which the equation in question was supposed to be linear. The design procedure leads to a nonlinear internal model complemented by an adaptively tuned high-gain error feedback.

Resource management in wireless systems This research has been mainly performed within the Sixth Framework Programme of the European Union in the projects DAIDA-

LOS II, EuQoS, IMAGES, WEIRD, SATSIX, M3CAST. These projects, performed within consortia involving major European universities/research centers, manufactures, and operators, aim at the research, design, development and standardisation of advanced wireless networks (UMTS, WiMax, IPv6 satellites, DVB-H). The scientific responsible for the above-mentioned projects is Francesco DELLI PRISCOLI.

In 2006, the DIS role in the framework of these projects mainly concerned the research, design, simulation (NS-2, OPNET), and implementation (Linux, Java, C++) of:

- Connection Admission Control (CAC) procedures;
- Dynamic Capacity Assignment (DCA) procedures;
- Congestion control and scheduling procedures; - Routing procedures;
- Broadcast and multicast procedures;
- Service discovery, service composition, and service provisioning.

In particular, within the context of the Images and EuQoS projects, an architecture was developed to formulate the whole resource management problem in a common framework, considering the heterogeneous network scenario. The objectives of this architecture are (i) to provide a detailed formulation of the Quality of Service (QoS) problem, both in the intra-domain case and in the inter-domain case, by means of a technology independent approach, particularly suited for guaranteeing the interworking among heterogeneous networks, and (ii) to clarify the interactions among the resource management procedures.

Thanks to the proposed technology independent approach, the QoS architecture encompasses both wireless and wired domains: by developing the different procedures within this framework, the obtained algorithms can be used on different network technologies with minor adjustments. The procedures were devoloped by following different methodologies, as for example: CAC procedures based on optimal control and dynamic programming, both for wired and wireless networks; DCA procedures based on model-based control and Smith predictor, both for satellite and terrestrial wireless networks; Routing procedures based on games theory. These contributions are reported in several papers submitted to major international conferences and reviews, as well as in plenty of deliverables (paper, software and hardware) relevant to the above-mentioned projects and master theses.

Stabilization of nonlinear systems In [1] we propose a certainty equivalence principle for the stabilization of nonlinear systems via measurement feedback, which clarifies the connection between the solution of a couple of Hamilton Jacobi inequalities (HJI) and the design constraints imposed on the control and the estimation error fed back in the control loop by the observer itself. Once a solution of these HJI's has been found, a measurement feedback controller can be directly implemented. This controller has different features with respect to classical controllers: in classical control schemes an observer consists of a

"copy" of the system plus a term proportional to the error between the actual measurement and the "estimated" measurement. In [1] we introduce a term which is nonlinear function of this error. This result is particularly powerful in conjunction with step-by-step strategies as illustrated by an application to feedforward systems.

In [2] we study the problem of stabilizing with large regions of attraction a general class of nonlinear system consisting of a linear nominal system plus uncertainties. A similar result was given in previous works; in [2] we prove that what was referred to in these works as "nonlinear coupling condition" can be reformulated in the control design as a "nonlinear rescaling" of the Lyapunov functions of the closed-loop system plus the requirement for a suitably faster convergence of the state estimation error. We obtain a paradigm very similar to the linear case, for which, if a couple of Riccati-like inequalities (state feedback and observer design) are satisfied, then a measurement feedback stabilizing controller can be readily found. Examples are given for showing improvements over the existing literature.

In [26] we study the problem of rendering integral input to state stable with respect to noise a general class of upper triangular nonlinear systems with uncertainty and measurement noise. We propose a novel step-by-step Lyapunov-based design, consisting of 1) splitting a n-dimensional system into n one-dimensional systems, each with its own state, inputs and measurement, 2) constructing a one-dimensional measurement feedback controller for each one-dimensional system, according to a certainty equivalence principle, and 3) selecting the parameters of these controllers so that their interconnection gives a measurement feedback controller for the n-dimensional system. The stability analysis is performed through filtered Lyapunov functions, which are Lyapunov functions with parameters being the output of suitable dynamical filters.

In [14] we introduce a new type of Lyapunov functions in a general framework particularly suitable for the analysis of systems with noise and uncertainty. These Lyapunov functions may depend on parameters possibly satisfying differential equations or inequalities. The main differences with respect to classical Lyapunov functions and classical tools for the design of composite Lyapunov functions are discussed through examples. A design tool for the design of composite filtered Lyapunov functions is given, and examples show improvements over existing literature.

In [15] we study the problem of rendering asymptotically stable in probability a general class of upper triangular nonlinear systems despite of uncertainties and noise modeled as a square integrable Markov process with independent increments.

Journals

[1] Battilotti S. A separation result for systems with feedback constraints, *Systems & Control Letters*, **55**, 369-375, 2006.

[2] Battilotti S. Robust detectability from the measurements plus state feedback stabilization imply semiglobal stabilization from the measurements, *IEEE Transactions on Automatic Control*, **51**, 1542-1548, 2006.

[3] Bruni C., Delli Priscoli F., Koch G., Marchetti I. An optimal approach to the connection admission control problem, *International Journal of Control*, **79**, 1237-1250, 2006.

[4] Bruni C., Delli Priscoli F., Koch G., Marchetti I. An innovative approach to the formulation of connection admission control problem, *Transactions on Engineering, Computing and Technology*, **18**, 166-173, 2006.

[5] Cusani R., Delli Priscoli F., Razzano G. Wireless LANs systems: An advanced resource assignment algorithm, *Wireless Personal Communications*, **39**, 24-40, 2006.

[6] De Persis C. On stabilization of nonlinear systems under data rate constraints using output measurements, *International Journal of Robust and Nonlinear Control*, **16**, 315-332, 2006.

[7] De Persis C. Nonlinear stabilizability via encoded feedback: The case of integral ISS systems, *Automatica*, **42**, 1813-1816, 2006.

[8] Delli Priscoli F., Inzerilli T., Munoz T. QoS provisioning in wireless IP networks, *Wireless Personal Communications*, **37**, 23-39, 2006.

[9] Delli Priscoli F., Marconi L., Isidori A. A new approach to adaptive nonlinear regulation, *SIAM Journal of Control and Optimization*, **45**, 829-855, 2006.

[10] Delli Priscoli F., Marconi L., Isidori A. Adaptive observers as nonlinear internal models, *Systems & Control Letters*, **55**, 640-649, 2006.

[11] Delli Priscoli F., Mannino C., Muratore M. Joint MAC scheduling and transport format choice for UMTS uplink transmission, *Wireless Personal Communications*, Published online 29 June 2006.

[12] Isidori A., Marconi L., De Persis C. Remote tracking via encoded information for nonlinear systems, *Systems & Control Letters*, **55**, 809-818, 2006.

[13] Kim J.-S., Yoon T.-W., Jadbabaie A., De Persis C. Input-to-state stable finite horizon MPC for neutrally stable linear discrete-time systems with input constraints, *Systems & Control Letters*, **55**, 293-303, 2006.

Conference proceedings

[14] Battilotti S. Filtered Lyapunov functions and their applications in the stability analysis of nonlinear systems, in *Proceedings of the 45th IEEE Conference on Decision and Control*, San Diego (CA), December 13-15, 2006.

[15] Battilotti S. Control of stochastic feedforward systems with square integrable noise and appended dynamics, in *Proceedings of the 45th IEEE Conference on Decision and Control*, San Diego (CA), USA, December 13-15, 2006.

[16] Bruni C., Delli Priscoli F., Koch G., Marchetti I. Connection admission control in cellular networks: A discrete time optimal solution, in *Proceedings 2006 IEEE INFOCOM*, Barcelona, Spain, April, 2006.

[17] Ceragioli F., De Persis C. Discontinuous control of nonlinear systems: Quantized and switched controls, in *Proceedings of the 45th IEEE Conference on Decision and Control*, San Diego (CA), USA, December 13-15, 2006.

[18] De Persis C., Jessen J.J., Izadi-Zamanabadi R., Schioler H. Internal flow management in a multi-zone climate control unit, in *Proceedings of the 2006 CCA/CACSD/ISIC*, Technische Universität München, Munich, Germany, October 4-6, 2006.

[19] Delli Priscoli F., Marconi L., Isidori A. A new approach to adaptive nonlinear regulation, in *Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems (MTNS) Conference*, Kyoto, Japan, July 24-28, 2006.

[20] McGregor N. K., Byrnes C. I., Isidori A. Results on nonlinear output regulation for MIMO systems, in *Proceedings of the 2006 IEEE American Control Conference*, Minneapolis (MN), USA, June 14-16, 2006.

[21] McGregor N. K., Byrnes C. I., Isidori A. Results on global robust output regulation, in *Proceedings of the 45th IEEE COnference on Decision and Control*, San Diego (CA), USA, December 13-15, 2006.

[22] Pietrabissa A., Anticoli Borza D. An approximate dynamic programming approach to admission control in WCDMA networks, in *Proceedings 2006 CCA/CACSD/ISIC*, Technische Universität München, Munich, Germany, October 4-6, 2006.

[23] Pietrabissa A., Delli Priscoli F., Fiaschetti A., Di Paolo F. A robust congestion control for communication networks with time-varying delays, in *Proceedings 2006 CCA/CACSD/ISIC*, Technische Universität München, Munich, Germany, October 4-6, 2006.

[24] Poli C., Pietrabissa A. Black-box modelling approaches for the prediction of microbiological bacterial growth, in *Proceedings of the 2006 CCA/CACSD/ISIC*, Technische Universität München, Munich, Germany, October 4-6, 2006.

[25] Praly L., Marconi L., Isidori I. A new observer for an unknown harmonic oscillator, in *Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems (MTNS) Conference*, Kyoto, Japan, July 24-28, 2006.

Submitted papers, technical reports and others

[26] Battilotti S. Lyapunov-based design of iISS feedforward systems with uncertainty and noisy measurements, accepted in the *SIAM Journal on Control and Optimization*, 2006.

[27] Bruni C., Delli Priscoli F., Koch G., Marchetti I. Discrete time optimal solution for the connection admission control problem, submitted to *Computer Networks*, 2006.

[28] Ceragioli F., De Persis C. Discontinuous control of nonlinear systems: Quantized and switched controls, to appear in *Systems & Control Letters*, 2007.

[29] De Persis C., Jessen J.J., Izadi-Zamanabadi R., Schioler H. A distributed algorithm for internal flow management in a multi-zone climate control unit, accepted in the *International Journal of Control*, 2006.

[30] Delli Priscoli F., Pompili D., A demand assignment algorithm based on a Markov modulated chain prediction model for satellite bandwidth allocation, preliminarly accepted in *Wireless Networks*, 2006.

[31] Delli Priscoli F., Santoro G. A control theory approach to dynamic capacity allocation in GEO satellite networks with QoS provision, submitted to the *International Journal of Control*, 2006.

[32] Marconi L., Praly L., Isidori A. Output stabilization via nonlinear luenberger observers, to appear in the *SIAM Journal of Control and Optimization*, 2007.

[33] Marconi L., Isidori A. A unifying approach to the design of nonlinear output regulators, to appear in *Advances in Control Theory and Applications*, Springer Verlag LNCIS Series, 2007.

[34] Pietrabissa A. An alternative LP Formulation of the admission control problem in multi-class networks, submitted to *Automatica*, 2006.

[35] Pietrabissa A. Admission control in UMTS networks based on approximate dynamic programming, submitted to the *European Journal of Control*, 2006.

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 was established in 1987. The following robotic equipment is currently available: the 8R-dof redundant manipulator *DEXTER* (by Scienzia Machinale); the two-link underactuated arm *Pendubot* (by Quanser), equipped with a vision system; the *Butterfly*, a simple mechanism for nonprehensile manipulation equipped with a vision system; seven mobile robots with two-wheel differentially-driven kinematics: *Magellan-Pro* (by IRobot), with a SICK laser range finder, an ultrasonic-infrared sensor suite and on-board pan-tilt camera, and a team of six mini mobile robots composed by one Khepera II (by K-Team), with infrared sensors, and five *Khepera III* (by K-Team) each with infrared and ultrasonic sensors and one of them additionally equipped with the HOKUYO laser range finder; two four-legged robot dogs *AIBO* (by Sony). The Laboratory is on the web at `http://www.dis.uniroma1.it/labrob`.
Active grants include the MIUR FIRB *TIGER* and the Telethon *ASPICE* national projects, as well as the following EU projects: PHRIDOM (PR project within EURON), CyberWalk and PHRIENDS (both STREP-IST projects within FP-6). In 2006, we have cooperated with the following foreign institutions: the *LAAS-CNRS* in Toulouse, and the *DLR* in Wessling (Germany). At the national level, we have collaborations with *Campus Biomedico*, *Fondazione Santa Lucia IRCCS* and *DIA–Università di Roma Tre* in Roma, *DII–Università di Siena*, *DIS–Università di Napoli Federico II*.

Group members Massimo CEFALO, Andrea CHERUBINI, Alessandro DE LUCA, Antonio FRANCHI, Luigi FREDA, Raffaella MATTONE, Giuseppe ORIOLO, Paolo ROBUFFO GIORDANO, Marilena VENDITTELLI.

Modeling and Control of Robots with Flexibility Joint elasticity is the main source of vibration in industrial robots, when harmonic drives, belts, or long shafts are used as transmission elements. We have shown in the past that dynamic feedback linearization can be successfully applied for trajectory tracking tasks. This solution, as well as other advanced control techniques for this class of manipulators, requires feedback from the full robot state (position and velocity on motor and link side of the elastic joints). These measurements are never available in practice. Several nonlinear observers have been proposed in the past, assuming different reduced sets of measurements. We have introduced in [15] a new observer which is based only on motor position sensing and on the use of accelerometers suitably mounted on the links of the robot arm. As a notable feature, the error dynamics on the estimated state becomes independent of the dynamic parameters of the robot links and can be tuned with standard decentralized linear techniques (locally to each joint). This observer has been experimentally validated for the three base joints of a KUKA KR15/2 industrial robot, and integrated in an observer-based feedback law.
Lightweight manipulators with very slender mechanical design usually imply the presence of link flexibility, with associated control difficulties (e.g., non-minimum phase of the end-effector position output). For regulation tasks, a PD control law with a suitable on-line gravity compensation term has been proposed in [16]. This control law achieves global asymptotic stabilization of any desired configuration using only measurements at the robot joints and not of the link deflection.

Underactuated Robots Underactuated mechanical systems (i.e., with less command inputs than generalized coordinates) raise very challenging planning and control issues. In [4], the control problem is addressed for the *Butterfly*, an interesting example of 2-dof underactuated system. This robot consists of a butterfly-shaped rotational link on whose rim a ball rolls freely. The control objective is to stabilize the robot at a given unstable equilibrium. To this end, an energy-based technique is developed which exploits the existence of heteroclinic trajectories.

Planning and Control for Nonholonomic Systems Wheeled vehicles in rolling contact with the ground or dexterous manipulation devices are robotic systems subject to nonholonomic (i.e., non-integrable) first-order differential constraints. A particularly interesting case arises when a manipulator arm is mounted on a nonholonomic mobile platform. Typically, these systems are kinematically redundant for the Cartesian tasks to be performed with the robot end-effector. A compact kinematic model for such nonholonomic mobile manipulators can be derived by combining the manipulator differential kinematics with the admissible differential motion of the platform. Based on this model, kinematic control and redundancy resolution schemes originally developed for standard

manipulators can be directly extended, in particular the Projected Gradient and the Reduced Gradient optimization-based methods [5]. See also the section on Visual Servoing.
A basic problem arising in planning the motion of nonholonomic systems among obstacles is the computation of the distance between the robot and the obstacles which takes into account the nonholonomic constraints (sub-Riemannian distance). This problem has been solved in [1] for the Reeds and Shepp car (one of the most used kinematic model for a car-like robot). In particular, by modeling both the robot and the obstacles as rigid objects of polygonal shape, the distance has been defined as the length of the shortest feasible (i.e., taking kinematic constraints into account) path between the robot's polygon perimeter to the boundary of the polygons representing the obstacles in the environment. The solution is based on Pontryagin's Maximum Principle, together with the transversality conditions accounting for the fact that the final robot orientation is free (the robot can crash into obstacles with any orientation). The solution has been generalized to the Dubins' car (a car that can move only forward) in [6].
Exploration of virtual worlds with unconstrained locomotion possibilities for the user is the main objective of the European research project *CyberWalk*. This will be achieved through the use of an actuated platform (the *CyberCarpet*) that compensates for the walker's locomotion in such a way to keep her/him close to the platform center. Since the platform has only two actuating devices (linear and angular), the corresponding control problem is similar to that of nonholonomic wheeled mobile robots. Based on a kinematic model of the system, a velocity control design achieving input-output decoupling and linearization has been proposed in [7]. The presence of control singularities in this scheme has been handled in [8]. Furthermore, the feedback stabilizing part of the control law, which is based only on the user's pose information, has been complemented by a feedforward term derived from an observer of the a walker's intentional velocity. Finally, we have considered in [17] the case when the *CyberCarpet* cannot be controlled by velocity inputs, but linear and angular acceleration commands must be provided. This is necessary, e.g., when the bounds on the platform accelerations have to be taken explicitly into account in order to comply with the physiological requirements for a 'natural walk' in the VR. In order to move the control design to the acceleration level, we have used, in particular, backstepping techniques and the theory of cascaded systems, relying in both cases on the already available velocity control laws.

Visual Servoing In the image-based visual servoing framework, error signals are directly computed from image feature parameters, thus obtaining control schemes which do not need neither a 3-D model of the scene, nor a perfect knowledge of the camera calibration matrix. However, the current value of the depth Z for each considered feature must be known. In [18] we have proposed a method for on-line estimation of the value of Z for point features, based on tools from nonlinear observer theory. By interpreting Z as a continuous unknown state with known dynamics, we build an estimator which asymptotically recovers the actual depth value for the selected feature.
For wheeled nonholonomic mobile robots equipped with an on-board pinhole camera, we have developed, in cooperation with the Università di Siena, an image-based visual

servoing algorithm based on epipolar geometry. The robot is steered toward a desired target object with no a priori knowledge of the 3D structure of the object [19]. In particular, the epipoles are first extracted by suitably processing the current and the desired image, and then driven to the desired location by a control law based on input-output linearization. The above approach has been extended to the case of on-board catadioptric (panoramic) camera in [9], in order to eliminate the problem of keeping the image features in the field of view during motion.
In [20], we have presented a two-level visual scheme for intercepting a moving target with a nonholonomic mobile robot. On the lower level, the pan-tilt platform carrying the on-board camera is controlled so as to keep the target at the center of the image plane. On the higher level, the relative position of the ball is retrieved from the pan/tilt angles through simple geometry, and used to compute a control law driving the robot to the target. The proposed visual interception method has been validated through simulations and experiments on the mobile robot *MagellanPro*.
We have also considered the visual servoing of nonholonomic mobile manipulators in [21], using the tools developed in [5]. The kinematic control schemes proposed therein are applied to the specific case of image-based visual servoing, where the NMM image Jacobian combines the interaction matrix and the kinematic model of the mobile manipulator. Comparative numerical results are presented for two case studies.

Motion Planning A contribution to the area of motion planning is given in [10], where a simple strategy is presented for improving the connectivity of probabilistic roadmaps by genetic post-processing. In particular, the objective is to increase the roadmap density in narrow passages, where many of the existing probabilistic planners perform poorly. To this end, we associate with each individual (i.e., to each robot configuration) an easily computable fitness function based on the distance between disjoint components of the roadmaps. Straightforward selection, crossover and (possibly) mutation operators are then applied to improve the quality of the population. Numerical results in different workspaces, including a well-known benchmark, have shown the effectiveness of the proposed strategy.

Sensor-based Exploration The probabilistic approach is being used also for reactive motion planning and exploration. In this area, we have proposed in recent years a frontier-based technique for sensor-based exploration of unknown environments by a mobile robot [14]. The method is based on the randomized incremental generation of a data structure called Sensor-based Random Tree (SRT), which represents a roadmap of the explored area with an associated safe region. The random mechanism for generating new configurations is biased towards unexplored areas.
In [11], the SRT method has also been modified so as to obtain an integrated exploration strategy, i.e., an algorithm which takes into account localization as well as map building when planning the next action. In particular, a continuous localization procedure based on natural features of the safe region is integrated in the scheme. Both the information gain and the localization potential are taken into account when evaluating the next can-

didate configurations to be explored. Extensive simulation, as well as experiments on the *MagellanPro* robot, shows the performance of the proposed technique.
Another outgrowth of the basic SRT method is the multi-robot exploration strategy presented in [22]. In this case, a collection of SRTs is built, with each SRT representing a roadmap of the area explored by one of the robot in the team with an associated collision-free region. To improve the exploration efficiency and to avoid conflicts, decentralized cooperation and coordination mechanisms are introduced, which can be implemented also in the case of a limited communication range.

Fault Detection and Isolation In the standard fault detection and isolation (FDI) problem for controlled plants, detection consists in generating on-line diagnostic signals in correspondence to potential faults that may affect system components; isolation occurs when each specific fault can be discriminated from all other faults or disturbances.
For general dynamic nonlinear systems affine in the inputs, the differential-geometric approach to standard FDI has been extended in [2] to two relaxed problems: detection and isolation of faults belonging to a given set, and construction of a minimal set of faults that can be detected and isolated and that contains an assigned set of faults (possibly, a singleton). Using these results, one can also determine weaker necessary (and sufficient) conditions that allow isolation of single faults under the assumption of their non-concurrency. These results have been experimentally validated on a robotic case study. In this framework, a suitable procedure has been proposed in [3] for modeling state sensors failures so as to yield a faulted model which is still affine in the (fault) inputs. The resulting fault inputs are always concurrent in blocks and an hybrid-type FDI scheme can be defined, based on continuous-time residual generators and on the combinatorial processing of their outputs. Considering multiple non-concurrent faults of sensors and actuators, the complete procedure has been presented for a three-tank fluid heating system.

Physical Human-Robot Interaction For robots in anthropic domains, safety and dependability issues in the robot mechanical design, control design, and software supervision have to be revisited. Focusing on the physical side of the problem (tasks with contact or strict cooperation between humans and robots, handling of unexpected collisions), a safer human-robot interaction requires a lightweight arm design and the introduction on purpose of compliant elements. In addition, quick collision detection and post-impact reaction control strategies are fundamental capabilities for a robot manipulator that shares its workspace with humans, with the goal of preventing severe injuries due to accidental contacts. A survey of the status of technologies and methodologies for safe human-robot interaction is given in [23].
In particular, elaborating on robot mechanical energy and generalized momentum, an efficient collision detection method that uses only proprioceptive robot sensors has been presented in [12]. The collision with the environment (including humans) may occur at any point along the robot and is detected (as a system fault) in the absence of extra force/torque or contact sensors. As soon as collision is detected, the controller reduces the apparent arm inertia and the robot is safely and smoothly driven away from the col-

lision area, using directional information gathered from the 'residual' signals generated during collision. The approach, first formally developed for rigid robot arms and then extended to the case of robots with elastic joints, has been successfully experimented on several human-robot collisions with the *DLR-III* lightweight manipulator.

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 [13], we present a project (funded by the Italian Telethon Foundation and in collaboration with Fondazione Santa Lucia) aimed at developing a system that provides remote control of home-installed appliances, including robotic devices such as the Sony *AIBO*. The design of the robot navigation system is described in [24]. Single step, semi-autonomous, and autonomous operating modes have been realized to provide different levels of interaction with the *AIBO*. In particular, autonomous navigation mode relies on a vision-based path planning/following module described in [25]. Automatic collision avoidance is integrated in all cases. The performance of the navigation system has been tested in simulation as well as experiments. Also, the system underwent clinical validation, in order to obtain a definitive assessment through patient feedback.

Journals

[1] P. Robuffo Giordano, M. Vendittelli, J.-P. Laumond, and P. Souères. Nonholonomic distance to polygonal obstacles for a car-like robot of polygonal shape. *IEEE Trans. on Robotics*, 22(5):1040-1047, 2006.

[2] R. Mattone and A. De Luca. Relaxed fault detection and isolation: An application to a nonlinear case study. *Automatica*, 42(1):109–116, 2006.

[3] R. Mattone and A. De Luca. Nonlinear fault detection and isolation in a three-tank heating system. *IEEE Trans. on Control Systems Technology*, 14(6):1158–1166, 2006.

Conference proceedings

[4] M. Cefalo, L. Lanari, and G. Oriolo. Energy-based control of the Butterfly robot. In *Proc. of 8th IFAC Symp. on Robot Control*, Bologna, I, 2006.

[5] A. De Luca, G. Oriolo, and P. Robuffo Giordano. Kinematic modeling and redundancy resolution for nonholonomic mobile manipulators. In *Proc. of 2006 IEEE Int. Conf. on Robotics and Automation*, pp. 1867–1873, Orlando, FL, 2006.

[6] P. Robuffo Giordano and M. Vendittelli. The minimum-time crashing problem for the Dubins' car. In *Proc. of 8th IFAC Symp. on Robot Control*, Bologna, I, 2006.

[7] A. De Luca, R. Mattone, and P. Robuffo Giordano. The motion control problem for the CyberCarpet. In *Proc. of 2006 IEEE Int. Conf. on Robotics and Automation*, pp. 3532–3537, Orlando, FL, 2006.

[8] A. De Luca, R. Mattone, and P. Robuffo Giordano. Feedback/feedforward schemes for motion control of the CyberCarpet. In *Proc. of 8th IFAC Symp. on Robot Control*, Bologna, I, 2006.

[9] G. L. Mariottini, G. Oriolo, and D. Prattichizzo. Image-based visual servoing for nonholonomic mobile robots with central catadioptric camera. In *Proc. of 2006 IEEE Int. Conf. on Robotics and Automation*, pp. 538–544, Orlando, FL, 2006.

[10] G. Oriolo, S. Panzieri, and A. Turli. Increasing the connectivity of probabilistic roadmaps via genetic post-processing. In *Proc. of 8th IFAC Symp. on Robot Control*, Bologna, I, 2006.

[11] L. Freda, F. Loiudice, and G. Oriolo. A randomized method for integrated exploration. In *Proc. of 2006 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 2457-2464, Beijing, PRC, 2006.

[12] A. De Luca, A. Albu-Schäffer, S. Haddadin, and G. Hirzinger. Collision detection and safe reaction with the DLR-III lightweight manipulator arm. In *Proc. of 2006 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pp. 1623–1630, Beijing, PRC, 2006.

[13] F. Cincotti, F. Aloise, F. Babiloni, M. G. Marciani, D. Morelli, S. Paolucci, G. Oriolo, A. Cherubini, S. Bruscino, F. Sciarra, F. Mangiola, A. Melpignano, F. Davide, and D. Mattia. Brain-operated assistive devices: The ASPICE project. In *Proc. of 1st IEEE/RAS-EMBS Int. Conf. on Biomedical Robotics and Biomechatronics*, pp. 817-822, Pisa, I, 2006.

Ph.D. thesis

[14] L. Freda. *Randomized Strategies for Sensor-based Robot Exploration*. Ph.D. Thesis, Università di Roma "La Sapienza", 2006.

Submitted papers, technical reports and others

[15] A. De Luca, D. Schröder, and M. Thümmel. An acceleration-based state observer for robot manipulators with elastic joints. Accepted for presentation at *2007 IEEE Int. Conf. on Robotics and Automation*, Roma, I, April 2007.

[16] L. Zollo, B. Siciliano, A. De Luca, and E. Guglielmelli. PD control with on-line gravity compensation for robots with flexible links. Accepted for presentation at *2007 European Control Conf.*, Kos, H, July 2007.

[17] A. De Luca, R. Mattone, and P. Robuffo Giordano. Acceleration-level control of the CyberCarpet. Accepted for presentation at *2007 IEEE Int. Conf. on Robotics and Automation*, Roma, I, April 2007.

[18] A. De Luca, G. Oriolo, and P. Robuffo Giordano. On-line estimation of feature depth for image-based visual servoing schemes. Accepted for presentation at *2007 IEEE Int. Conf. on Robotics and Automation*, Roma, I, April 2007.

[19] G. L. Mariottini, G. Oriolo, and D. Prattichizzo. Image-based visual servoing for nonholonomic mobile robots using epipolar geometry. Accepted for publication in *IEEE Trans. on Robotics*, August 2006.

[20] L. Freda and G. Oriolo. Vision-based interception of a moving target with a nonholonomic mobile robot. Submitted in revised form to *Robotics and Autonomous Systems*, December 2006.

[21] A. De Luca, G. Oriolo, and P. Robuffo Giordano. Image-based visual servoing schemes for nonholonomic mobile manipulators. Accepted for publication in *Robotica*, Special Issue on Mobile Manipulators: Basic Techniques, New Trends & Applications, November 2006.

[22] A. Franchi, L. Freda, G. Oriolo, and M. Vendittelli. A randomized strategy for cooperative robot exploration. Accepted for presentation at *2007 IEEE Int. Conf. on Robotics and Automation*, Roma, I, April 2007.

[23] A. De Santis, B. Siciliano, A. De Luca, and A. Bicchi, The PHRIDOM atlas of physical human-robot interaction. Submitted to *Mechanism and Machine Theory*, September 2006.

[24] A. Cherubini, G. Oriolo, F. Macrì, F. Aloise, F. Cincotti, and D. Mattia. Development of a multimode navigation system for an assistive robotics project. Accepted for presentation at *2007 IEEE Int. Conf. on Robotics and Automation*, Roma, I, April 2007.

[25] A. Cherubini, G. Oriolo, F. Macrì, F. Aloise, F. Cincotti, and D. Mattia. A vision-based path planner/follower for an assistive robotics project. Accepted for presentation at *1st Int. Work. on Robot Vision*, Barcelona, E, March 2007.

3.3 Management science

3.3.1 Combinatorial Optimization

The research of the Combinatorial Optimization Group is mostly devoted to theoretical and computational aspects related to i) design of telecommunication networks and ii) automated data correcting.

The group is currently cooperating with Maastrich University, Konrad Zuse Zentrum fr Informationstechnik Berlin, Università di Roma Tor Vergata, Università dell'Aquila, Università di Lecce and Politecnico di Milano. Also, it is cooperating with the Italian Public Authority for Telecommunication and with ISTAT. It is currently involved in several national and international research project, including the MIPAF project ADM (Agricultural Data Mining), the MIUR projects M3-CAST and APICE (both devoted to Wireless Network Planning), and the European IST projects SAILOR (devoted to third generation mobile wireless networks) and IMAGES (devoted to QoS in next generation IP networks).

Group members Renato BRUNI, Silvia CANALE, Carlo MANNINO, Sara MATTIA, Antonio SASSANO.

Network design and location The p-Median is a fundamental location problem. It consists of determining p nodes (the median nodes) minimizing the total distance from the other nodes of the graph. Its relevance stems from the relationship with the stable set problem and from its crucial role as a basic building block of more complex location problems. In [10] we describe a Branch-and-Cut-and-Price algorithm yielding provably good solutions for instances with up to 3795 nodes. Key ingredients of the algorithm are a delayed column-and-row generation technique, the exploitation of the special structure of the formulation and the addition of provably good cutting planes to strengthen the formulation and limit the size of the enumeration tree.

Radio and television broadcasting, cellular mobile telecommunication systems, satellite-based cellular networks and many other important civil and military applications require a huge number of antennas to be located on the territory so as to maximize the coverage or some kind of measure of the service. All wireless applications make use of the radio spectrum to establish communications between a transmitter and a receiver. Since the radio spectrum is a limited resource, an important phase in wireless network design is to efficiently solve the Frequency Assignment Problem (FAP), that is the problem of assigning available radio frequencies to the base stations of a radio network in such a way that interference requirements are satisfied and suitable objective functions are optimized. A short history of this problem along with standard models and algorithms is reviewed in [14]. A new solution approach is then presented in [8]: such an approach outperformed other known approaches on the famous FAP-web testbed (ZIB-Berlin). Integer linear programs and solution algorithms to the problem of joint optimization of frequencies and emission powers for terrestrial digital broadcasting are presented in [1].

The problem of designing good quality and low cost networks arises in several real-life applications like transportation and telecommunication ones. One of the most impor-

tant problems of this kind is the Network Loading Problem (NLP). The problem is the following: given a set of traffic demands to be routed between the nodes of the network, the goal is to choose capacities for the edges of the graph such that all the demands can be shipped simultaneously, minimizing at the same time the capacity installation cost. The aim of the work is the study of the properties of the Network Loading polyhedron, in order to caracterize all valid inequalities, give condition for these inequalities to be facet-defining, develop separation tecniques to be used within Branch&Cut framework to solve the problem, test the algorithm using real-life unsolved instances. The results are reported in [11].

Computational Molecular Biology, Peptide Sequencing Several computationally demanding problems arise from biological and medical research. Important examples are sequencing problems: data obtained from the mass spectrometry analysis of a generic compound, constituted, according to specific chemical rules, by an unknown sequence of components, should be processed in order to determine such sequence. By formulating a mathematical model for such combinatorial problem, structural limitations of known methods are overcome, and efficient solution algorithms based on branching are presented in [3, 9]. 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 [16, 4].

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 [15]. 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.

Data Mining, Classification, Clustering and Information Reconstruction Data Mining is in general the process of extracting useful infomation from large amounts of data. In particular, important data mining tasks are Classification, Clustering and Information Reconstruction.

Given a set of data which are already grouped into classes, the Classification problem consists in predicting which class each new data belongs to. With respect to standard logic based classification procedures, enhancements based on probability considerations are presented: the quality of each cut-point is evaluated, so that a weighted set covering problem for the selection of the optimal support set is solved in [17]. The same problem is also modeled and solved as a binary knapsack problem in [6].

When dealing with large datasets, a common problem is the individuation of errors and the reconstruction of the corrupted information. This is called Error Correction, or Information Reconstruction. In order to shorten computational times for very large

datasets, a preventive subdivision of the data should be carried out by means of a specialized Clustering procedure. Such procedure, called algorithm of the spherical neighborhoods [5], has been developed for hierarchical demographic data and shows better performances than other known Clustering algorithms.

Machine Learning and Boosting Boosting techniques have emerged as one of the most promising and effective algorithms for supervised learning. The boosting approach aims at defining an ensemble of base classifiers chosen among a (usually) huge family D called dictionary. The research focuses on the efficient solution method of boosting problem with respect to the dictionary D of linear classifiers. The dictionary D is very general and its members were often used for data classification (e.g. Perceptron algorithm, Support Vector Machine, Decision Tree, Set Covering Machine with data dependent hyperplanes). Because of the huge amount of base classifiers, solving the boosting problem with respect to the entire dictionary D may turn out to be practically impossible. In [7] a column generation technique is proposed to efficiently solve the LP boosting formulation. We introduce a pricing problem that, starting from a current solution of the master problem, selects a linear classifier with the best compromise in terms of generalization capability and training error. Results on some data sets of practical size and related predictive accuracies are compared with other Machine Learning approaches.

Using Mixed Integer Programming to Solve Power Grids Blackout Problems During the last decade, several large-scale failures of national power transmission networks took place. The most recent were the blackouts of the U.S. Northeast and Eastern Canada of August 2003, and the September 2003 blackout that affected Italy. In addition, Brazil experienced large blackouts in 1999. These blackouts affected large numbers of people over wide geographical areas, with substantial economic impact. Had the event lasted more than a few days, the human cost would have been quite large. The issue of how to prevent – or at least make less likely – catastrophic blackouts in a large network is complex, involving engineering, economic and even political issues. In [12] we consider two optimization models to address the following generic question: given a network, how do we protect it at minimum cost so as to make it (more likely to) survive a potential cascade?

Journals

[1] C. Mannino, F. Rossi, S. Smriglio, The Network Packing Problem in Terrestrial Broadcasting. *Operations Research* 54 (3), 611-626, 2006.

Articles in books

[2] E. Amaldi, A. Capone, F. Malucelli, C. Mannino, Optimization problems and models for planning cellular networks, In M. Resende and P. Pardalos, editors, *Handbook of Optimization in Telecommunication*, Springer Science, 2006.

Conference proceedings

[3] R. Bruni, On Accurate and Automatic Peptide De Novo Sequencing, In *Proceedings of Perspectives of Metabonomics and Proteomics Investigations in Clinical Science*, Roma, Italy, 2006

[4] R. Bruni, De Novo Peptide Sequencing via Tandem Mass Spectometry and Propositional Satisfiability, In *Proceedings of 1st FIMA International Conference Models and Methods for Human Genomics*, Aosta, Italy, 2006.

[5] R. Bruni, Clustering for improving Information Reconstruction (Extended abstract), In *Proceedings of the annual conference AIRO*, Cesena, Italy, 2006.

[6] R. Bruni, Fast and Accurate Classification using Discretization and Binary Knapsack, In *Proceedings of the AIRO winter International Conference*, Belluno, Italy, 2007.

[7] Canale, S. and Sassano, A. Boosting in large dictionaries with a column generation approach. In *Proceedings of the XXXVII Annual Conference of the Italian Operations Research Society (AIRO 2006)*, Cesena, Italy, September 2006.

Submitted papers, technical reports and others

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

[9] R. Bruni, A Combinatorial Approach for finding the Combination or the Sequence of a Polymer, submitted to *Algorithmic Operations Research*.

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

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

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

[13] F. Delli Priscoli, C. Mannino, M. Muratore, Joined MAC scheduling and Transport Format choice for UMTS uplink transmission, to appear in *Wireless Personal Communications*.

[14] K. Aardal, S.P.M. van Hoesel, A. Koster, C. Mannino, and A. Sassano, Models and Solution Techniques for Frequency Assignment Problems, to appear in *Annals of Operations Research*.

[15] R. Bruni and A. Santori, New Updating Criteria for Conflict-Based Branching Heuristics in DPLL Algorithms for Satisfiability, to appear in *Discrete Optimization*.

[16] R. Bruni, Solving Peptide Sequencing as Satisfiability, to appear in *Computer and Mathematics with Applications*.

[17] R. Bruni, Reformulation of the Support Set Selection Problem in the Logical Analysis of Data, to appear in *Annals of Operations Research*.

3.3.2 Industrial Economics

The group of Industrial Economics mainly investigates the theoretical explanations and empirical implications of three interrelated phenomena: (i) technological innovation, (ii) strategic behavior of Multinational Enterprises (MNE) in R&D intensive industries, (iii) national and multilateral policies on foreign direct investment (FDI) and globalization. The main research topics are connected with the analysis of FDI and R&D in oligopolistic industries. Also aspects of regulation and competition policy are dealt with. We have been collaborating with several European Universities and research institutes, such as SPRU (Sussex University), UK; University of Reading, UK; Universitad Complutense de Madrid, Spain; Norwegian Institute of Foreign Affairs (NUPI), Norway.

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

Production and R&D Internationalization A first line of investigation examines the trade-offs faced by a multinational company when choosing whether to assign a foreign subsidiary an active role in innovation, thus deciding if its R&D should be centralized or, at least partly, decentralized. The model focuses on how the interplay of internal and external knowledge flows interacts with the nature of the host market competition, to influence the choice of the multinational company to effectively distribute internationally its R&D. Our analysis addresses both the case of R&D undertaken abroad in association with production and that of R&D labs alone [4]. A second strand of research analyzes the interaction between firms' international strategy and innovative performance in an international oligopoly characterized by localized technological spillovers. In particular, we have investigated whether the possibility to absorb technological knowledge operating in another country can be an incentive for a firm to invest abroad ("technological sourcing through FDI"). Obviously, also local firms take advantage of the closer location of the multinational firm, absorbing more quickly the technological knowledge produced by the latter. With the introduction of 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].

Cross-border Mergers and Acquisitions and Technology Transfer This line of research has been devoted to identify the optimal FDI mode (greenfield investment or acquisition) in a two country, two firm Cournot model with differing technological levels and country sizes, allowing for asymmetric equilibria. A firm entering the foreign market through greenfield investment has to pay a set up cost, while entry through acquisition involves a bargaining process which determines who will buy whom and at what price. The model explicitly allows for M&A implementation costs. International transfer of technology is

also costly, but an acquisition allows the firm to choose the best technological practice in each country. It is found that lower greenfield set up costs (multilateral investment liberalisation) may actually increase the incentives for acquisition. Furthermore, it is shown that a technological leader from a small country needs not only a strong technological lead in order to be the acquirer, but also an efficient know-how management system [3].

Obstacles to Innovation and Multinational Firms in the Italian Regions This research project analysed how firm, sector and region-specific features affect the probability of perceiving as important the obstacles to innovation. 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 important [2, 5].

Regulation and Competition Policy This strand of research investigates alternative regulatory policies aimed at affecting the viability of price discrimination by a regulated incumbent firm. It is well-known that price capped firms enjoy a large degree of pricing discretion that may harm both consumers and the development of competition. We built up a stylized model of an industry with product differentiation where there are (potentially) two firms, an incumbent and an entrant (or a competitive fringe). We studied how two different regulatory schemes - Relative and Absolute - might influence pricing decisions by the incumbent firm, the development and the extent of competition, and social welfare. We found that the Relative regime is not particularly effective in protecting captive consumers. However, this regulatory rule is more able to foster competition, as it may induce entry by some firms that would not be active under the Absolute regime or a greater supply being the number of firms invariant. While the effects on aggregate welfare are not clear-cut, there is some evidence that the Relative regime is more likely to increase consumers' surplus and social welfare the more efficient are the competitors [1].

Underprovision of Quality and Regulation Another line of research has aimed at analysing the behaviour of sellers in a market for an experience good, where it is unfeasible to credibly signal quality. We focused on a segmented market where firms, due to a different level of initial investment in human capital, are distinguished into low-type and high-type ones. We found that, with asymmetric information, both low-type and high-type firms choose an optimal quality strictly lower than under full information.

Equilibrium profits and consumers' welfare are reduced too. A Self-Regulating Organisation (SRO) is thus introduced: local monopolists can join the association to commit to some minimum quality standard (MQS). It is shown that if all club members are correctly perceived to comply with the MQS, prices and qualities would be set at the same level as with full information. A SRO represents a self-enforcing credible mechanism if there is an incentive for each member to punish deviant members (for both types). Finally, 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 [7].

Journals

[1] A. Iozzi, R. Sestini, and E. Valentini. Pricing Discretion and Price Regulation in Competitive Industries. *Journal of Regulatory Economics*, 29, 151–165, 2006.

Articles in books

[2] S. Iammarino, F. Sanna-Randaccio and M. Savona. Obstacles to innovation and multinationals firms in the Italian regions. Firm-level evidence from the Third Community Innovation Survey. In A. Tavares and A. Teixeira, editors, *Multinationals, Clusters and Innovation: Does Public Policy Matters?* pages 63–87. Palgrave, MacMillan, New York. 2006.

Conference proceedings

[3] L. Grunfeld and F. Sanna-Randaccio. Who buys whom in international oligopolies with FDI and technology trasfer? In *Proceedings of the AIB 2006 Annual Conference, Beijing, China (cd-rom)*.

Submitted papers, technical reports and others

[4] F. Sanna-Randaccio and R. Veugelers. Multinational knowledge spillovers with centralized versus decentralized R&D: a game theoretic approach. To appear in *Journal of International Business Studies*.

[5] S. Iammarino, F. Sanna-Randaccio and M. Savona. Multinationals Firms and Obstacles to Innovation. Evidence from the Italian Community Innovation Survey (CIS3). Submitted.

[6] M.L. Petit, F. Sanna-Randaccio, and R. Sestini. Localized Knowledge Flows and Foreign Direct Investment with Endogenous R&D: a Dynamic Analysis. Submitted.

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

3.3.3 Industrial Organization and Management

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

- regulation and competition in the pharmaceutical industry;
- signalling models in international oligopolistic competition;
- regulation and competition in network industries;
- auction-based market mechanisms;
- multicriteria decision making and corporate strategy;
- accounting and finance.

We have worked on a number of applied research projects funded by public institutions and firms. In particular, we have analysed for Wind Telecomunicazioni S.p.A. the implementation problems of the new regulatory framework for electronic communications markets within the European Union; in this context we have carried out an in depth analysis of the development of competition, both in fixed and mobile telephony markets, focusing on the regulatory intervention and firms' strategies. At present we are involved in the following research projects: MIUR (PRIN) "Modelli e metodi per l'analisi degli investimenti e delle scelte tecnologiche nei settori dell'energia elettrica e delle telecomunicazioni", MIUR (FISR) "INTERAGRO metodi e strumenti per la supply chain INTEgRata nell AGRO alimentare". We have organized the XVII national conference of the AiIG (Associazione italiana di Ingegneria Gestionale) and edited its proceedings [2].

Group members Alessandro AVENALI, Anna D'ANNUNZIO, Domenico LAISE, Claudio LEPORELLI, Gianluigi MARIANI, Giorgio MATTEUCCI, Alberto NASTASI, Pier Luigi PICCARI, Pierfrancesco REVERBERI.

Regulation and competition in the pharmaceutical industry National regulation generates price differentials between countries stimulating arbitrage by international distributors (Parallel Trade - PT). Harmed manufacturers counteract using vertical price-squeeze or non-price discrimination. Concerning the incentives to invest in product quality in the presence of international arbitrage, we show that: i) PT may increase investments if the re-imported product is of lower quality than the domestic product, but reduces investments with perfect substitutes; ii) price regulation (with PT) raises investments when the investment cost is not too convex; iii) the regulated price determines whether quality is exported, but does not affect marginal investment incentives. These findings dilute theoretical and policy concerns about the effects of PT on welfare (including investments) [11].

Signalling models in international oligopolistic competition We carry out an analysis of the entry strategies in oligopolistic industries in the presence of asymmetric information. In particular we consider a context where a home firm signals her private cost information by expanding in a foreign firm's country. Credible signalling to deter counter-entry may occur through a direct investment (but not through exports), and may even

entail entering an unprofitable market. While this produces social benefits, uninformative signalling may be welfare-reducing. Hence, we argue that moderate to high location costs may be socially desirable. We also show that there are not simple monotonic relationships between technology/demand conditions and firms' entry modes. Thus, the signalling interpretation of international expansion makes it possible to explain some controversial empirical findings on a theoretical ground [16].

Regulation and competition in network industries Our research in network industries focuses on both technological choices and regulatory policies in the electric and telecommunication sectors. In particular we provide models based on a game theoretic approach coherent with the market structures determined by both the existing regulatory frameworks and technological peculiarities of electric and telecommunication networks. As regards the telecommunications industry, our line of research aims at analyzing and modelling the entry process of alternative operators. In particular, we intend to verify the importance of regulatory policies in i) striking the balance between fostering competition and rewarding the incumbents' investments; ii) obviating strategic and structural entry barriers; iii) promoting, when desirable from a dynamic efficiency point of view, the development of alternative infrastructures [7]. In [3, 10], we address the main implementation issues of the regulatory paradigm of the ladder of investment: i) we introduce a dynamic access pricing rule that induces efficient investment in alternative infrastructures; ii) we evaluate the effects of imposing a sunset clause on regulation; iii) we identify the circumstances under which the proposed access charge schedule is subject to the regulatory commitment problem, and suggest a suitable adaptation to the rule that solves the problem; iv) we derive some insights about whether and when this regulatory paradigm strikes the right balance between promoting facility-based competition and remunerating the incumbent's investments. In [9] we show that access price regulation is welfare-enhancing, since it fosters competition while preserving the incumbent's investment incentives. This result is robust to four model specifications: i) the regulator credibly commits before the investment stage; ii) there exist consumer switching costs; iii) the rival firm considers (partial) backward integration; iv) the access owner is vertically separated. Thus, we reverse some negative literature findings and dilute policy concerns about the effects of behavioural and structural regulation on welfare (including investments). In [6] we carry out an analysis of private incentives and social desirability of bundled offers practiced by a fixed telephony incumbent operator. We show that bundling may allow the incumbent to strategically foreclose the market to those entrants offering subsets of services included in the incumbent's bundle. If the alternative operator offers high quality services, bundling may results detrimental from a social welfare point of view. In such a case a regulatory authority should introduce suitable price tests in order to prevent foreclosure while preserving the benefits of bundled offers. In [5] we analyze the dynamic effects related to the introduction of non-reciprocal termination charges based on structural asymmetries between operators. Formally, we investigate whether introducing endogenous pricing rules for termination services recognizing the disadvantages related to late market entry may help to pursue dynamic efficiency. This

analysis is motivated by the fact that the existing literature has not yet provided exhaustive answers whether the introduction of asymmetric tariffs may induce firms to invest sub-optimally or, on the contrary, stimulate competition and investments as well. As regards the electricity industry, in [8] we have elaborated a model reflecting the main aspects of the italian electric sector, such as the power generation segment and both wholesale and retail market mechanisms. In this framework, we have analyzed the effects of introducing full retail competition on volumes of both forward and spot sales, wholesale prices and market power of generators. We have further investigated on the investment incentives in power generation of the competitive fringe operators.

Auction-based market mechanisms We study how scarce resources can be traded via auction mechanisms. In particular, we focus on combinatorial auctions, which enhance the efficiency of market exchanges in environments characterized by complementarity or substitutability relations between the goods at sale [1]. However, this type of auction requires dealing with hard optimization problems, that require specific solution techniques [12].

Multicriteria managerial decision making Our research illustrates the advantages of the multicriteria methodology, founded on the notion of outranking methods, applied to managerial decision making problems. Outranking paradigms are satisfacing - heuristic and not optimizing algorithms, able to make effective and formally robust multicriteria choice without the aggregation of the set of conflicting criteria into a single objective function. Bringing outranking methods into managerial economics would allow to: 1) get more realism, 2) to strengthen the implementation of pragmatic methods of choice, 3) integrate outranking methods into behavioral decision making, 4) build a truly non-neoclassical managerial economics [4, 14, 15]. In [16] 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 (offered or required) and prices. Data offer may include bundling schemes, whereby different types of data are offered together with a single associated price and quality. We describe a brokering algorithm for obtaining data from peers, by minimizing the overall cost under quality requirements constraints. The algorithm extends query processing techniques over multiple database schemas to automatically derive an integer linear programming problem that returns an optimal matching of data providers to data consumers under realistic economic cost models.

Journals

[1] A. Avenali and A. Bassanini. Simulating combinatorial auctions through automated rational agents. *Decision Support Systems*, 43, pp.211-228, 2006.

Book

[2] C. Leporelli, editor. *Reti, servizi e competitività delle imprese. Atti della XVII Riunione scientifica AiIG*, Aracne Editrice, 2006.

Articles in books

[3] A. Avenali, G. Matteucci and P. Reverberi. Dynamic access pricing and incentives to invest in alternative infrastructures. In Leporelli C. editor, *Reti, servizi e competitività delle imprese. Atti della XVII Riunione scientifica AiIG*, Aracne Editrice, 2006.

[4] L. Biggiero, G. Iazzolino and D. Laise. Multicriteria Valuation of Business Strategies. In Leporelli C. editor, *Reti, servizi e competitività delle imprese. Atti della XVII Riunione scientifica AiIG*, Aracne Editrice, 2006.

[5] C. Cambini, C. Leporelli and P. Reverberi. Proprietà e impatto delle regole asimmetriche di terminazione su reti telefoniche. In Leporelli C. editor, *Reti, servizi e competitività delle imprese. Atti della XVII Riunione scientifica AiIG*, Aracne Editrice, 2006.

[6] A. D'Annunzio. Bundling e decisioni di entrata nei mercati delle comunicazioni elettroniche. In Leporelli C. editor, *Reti, servizi e competitività delle imprese. Atti della XVII Riunione scientifica AiIG*, Aracne Editrice, 2006.

[7] C. Leporelli. Le ICT e lo sviluppo del paese: concorrenza e regolamentazione per l'innovazione. In De Vincenti C. and Vigneri A. editors, *Le virtù della concorrenza. Regolazione e mercato nei servizi di pubblica utilità* , Collana "Quaderni di Astrid", Il Mulino, 2006.

[8] G. Mariani. Dal monopolio regolato alla full retail competition in Italia: effetto su prezzi, potere di mercato ed incentivi agli investimenti nel settore elettrico. In Leporelli C. editor, *Reti, servizi e competitività delle imprese. Atti della XVII Riunione scientifica AiIG*, Aracne Editrice, 2006.

Conference proceedings

[9] A. Avenali, G. Matteucci and P. Reverberi. One-way access pricing, imperfect competition and network investments, *European Association for Research in Industrial Economics EARIE Conference 2006*, Amsterdam, Netherlands, August 2006.

[10] A. Avenali, G. Matteucci and P. Reverberi. Dynamic access pricing and incentives to invest in alternative infrastructures. *International Telecommunications Society ITS Conference 2006*, Amsterdam, Netherlands, August 2006.

[11] G. Matteucci and P. Reverberi. Parallel trade, quality investments and regulation, *European Association for Research in Industrial Economics EARIE Conference 2006*, Amsterdam, Netherlands, August 2006.

Submitted papers, technical reports and others

[12] A. Avenali. Resolution Branch and Bound and an Application: the Maximum Weighted Stable Set Problem. *Operations Research*, accepted for publication.

[13] A. Avenali, C. Batini, P. Bertolazzi and P. Missier. Brokering infrastructure for minimum cost data procurement based on quality-quantity models. Submitted.

[14] L. Biggiero and D. Laise. On Choosing Governance Structures: Theoretical and methodological issues. *Human Systems Management*, forthcoming.

[15] G. Iazzolino and D. Laise. On Shareholder Value Analysis: Maximizing and Satisfacing Paradigms. In Linda M. Cornwall editor, *Banking and Finance Issues and Developments*, Nova Science Publishers, N.Y. (forthcoming).

[16] A. Nastasi and P. Reverberi. Foreign market entry strategies under asymmetric information, *Review of international economics*, forthcoming.

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, Lorenzo FARINA and Ilaria MOGNO (PhD student)

Embedded and Reactive Real-Time Systems in Management Embedded systems are electronic components integrated onto a physical plant. Automotive electronic design is certainly one of the most attractive and promising application domains for embedded systems. In fact, in today cars, the electronic control system is a networked system with an embedded controller dedicated to each subsystem, e.g. engine control unit, gear-box controller, anti-lock braking system (ABS), dashboard controller, and vehicle dynamic control (VDC). The embedded controllers interact by communicating over a network and system integration has become a nightmare in the automotive industry. On one hand, this is due to the lack of an overall understanding of the interplay of sub-systems and of the difficulties encountered in integrating very complex parts. On the other hand the complexity of the embedded controllers is necessary in order to comply with ever increasing demands on functionality and time-to-market pressure. In Reference [1] the typical design flow for embedded controllers adopted by the automotive industry is presented and challenging problems and opportunities identified.

The publications relevant to this area are: [1, 6].

Computational Optimization in Systems Biology Computational optimization in systems biology is a research program that links biologists and engineers in a multi-disciplinary approach to the systemic analysis of large scale and complex dynamical biological phenomena. The main interest is on theoretical aspects of modelling (positive systems) and on applicative topics in systems biology. The main results of the research in the area of positive systems are presented in reference [2] where the set of reachable states with positive controls has been studied. The geometrical properties (polyhedrality) of such set are characterized on the basis of the spectrum of the dynamic matrix. The interest for having polyhedral reachable sets is motivated by applications, since it is equivalent to finite-time reachability. Main results in the area of systems biology are presented in reference [8] where topological properties, related to the presence of double mutation lethality, are studied. We proved that, using experimental and synthetical data found in the literature, the position of enzyme pairs within the Saccharomices cerevisiae (yeast) metabolic network provides useful indications on their lethality in double mutants. In reference [4] a state-of-the-art review on the network analysis approach in systems biology is presented and critically discussed.

The publications relevant to this area are: [2, 4, 7, 8, 12, 13].

Signal Processing and Computer Vision Digital signal processing is concerned with the theoretical and practical aspects of representing and extracting information from real data; it has a significant impact in most of the scientific and technical areas of management sciences. Current applications of interest in the research group are within the areas of industrial engineering [19], man-machine interaction and medical technology [5], science of materials and mechanical structures fault diagnosis [14]. Advanced applications include the real-time analysis of videosequences in the framework of Human Computer Interface for disabled people, and in the development and design of surveillance systems for active monitoring of public areas. Our study lies within the framework of the variational approach to the image segmentation, formulated as a global optimization problem [16]. The novelty introduced consists in the development of a discrete level set approach that retains the accuracy of the continuum models based on nonlinear diffusion equation, but it is by far more numerically efficient. This makes real time applications really feasible.

The publications relevant to this area are: [3, 5, 9, 10, 11, 14, 15, 16, 17, 18, 19, 20].

Journals

[1] Balluchi A., Benvenuti L., Ferrari A. and Sangiovanni-Vincentelli A., Hybrid systems in automotive electronics design, *International Journal of Control*, 79, 375-390, 2006.

[2] Benvenuti L. and Farina L., The geometry of the reachability set for linear discrete-time systems with positive controls, *SIAM Journal on Matrix Analysis*, 28, 306-325, 2006.

[3] Benvenuti L. and Farina L., Nonnegative matrices in digital signal processing, *Signal Processing*, 89, 2388-2392, 2006.

[4] Palumbo M.C., Farina L., Colosimo A., Tun K., Dhar P.K. and Giuliani A., Networks everywhere? Some general implications of en emergent metaphor, *Current Bioinformatics*, 1, 219-234, 2006.

[5] De Santis A., Iacoviello D., Optimal segmentation of pupillometric images for estimating pupil shape parameters, *Special Issue on "Medical Image Segmentation" in Computer Methods and Programs in Biomedicine*, 84, 174-187, 2006.

Conference proceedings

[6] A. Balluchi, Benvenuti L., Di Benedetto M. D., Villa T. and Sangiovanni-Vincentelli A., Idle speed control - a benchmark for hybrid system research, *2nd IFAC Conference on Analysis and Design of Hybrid Systems*, Alghero, Italy, 2006

[7] Mogno I., Farina L., Gardner T., Identification of transcription logic-gate dynamics in Escherichia coli, *International Conference on Intelligent Systems for Molecular Biology*, 6-10, Fortaleza, Brazil, 2006

[8] Palumbo M.C., Farina L., Giuliani A. and Colosimo A., Coupled functional criticalities in metabolic networks, *First Maga Circe Conference on Metabolic Systems Analysis*, Sabaudia, Italy, 2006

[9] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Microstructure features identification in ferritic-pearlitic ductile iron, *CompImage-Computational Modelling of Objects Represented in Images: Fundamentals, Methods and Applications*, Coimbra, Portugal, 2006

[10] De Santis A., Iacoviello D., Discrete level set segmentation for pupil morphology characterization, *CompImage- Computational Modelling of Objects Represented in Images: Fundamentals, Methods and Applications*, Coimbra, Portugal, 2006

[11] Cavallini M., De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Analisi dell'Influenza del rapporto di carico sulla propagazione della cricca di fatica in una ghisa sferoidale ferrito-perlitica mediante sperimentazione e reti neurali artificiali, *AIM, Convegno Nazionale- Innovazione: strumento e strategia per lo sviluppo*, Milano, Italy, 2006

Submitted papers, technical reports and others

[12] Farina L., De Santis A., Morelli G. and Ruberti I., Dynamic measure of genes coregulation, *IET Proceedings Systems Biology*, to appear.

[13] Faith J.J., Hayete B., Thaden J.T. , Mogno I., Wierzbowski J, Cottarel G., Kasif S., Collins J.J., Gardner T.S., Large-Scale Mapping and Validation of Escherichia coli Transcriptional Regulation from a Compendium of Expression Profiles, *PLoS Biology*, to appear.

[14] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Optimal Binarization of Images by Neural Networks, *Pattern Analysis and Applications*, to appear.

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

[16] De Santis A., Iacoviello D., Discrete level set approach to image segmentation, submitted to *International Journal of Computer Vision*, 2006.

[17] De Santis A., Di Bartolomeo O., Iacoviello D., Iacoviello F., Quantitative shape evaluation of graphite elements in ductile iron, submitted to *Material Characterisation*.

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

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

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

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; 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 2006, the Nonlinear Optimization group has been mainly involved in the MIUR–FIRB National Research Program "Large Scale Nonlinear Optimization" and in the MIUR–PRIN National Research Program "Problemi, metodi e algoritmi innovativi nell'Ottimizzazione Nonlineare".

Group members Gianni DI PILLO, Francisco FACCHINEI, Giovanni FASANO [INSEAN], Luigi GRIPPO, Giampaolo LIUZZI, Stefano LUCIDI, Laura PALAGI, Veronica PICCIALLI, Arnaldo RISI [IASI-CNR], Massimo ROMA, Marco SCIANDRONE [IASI-CNR].

Unconstrained Optimization The research in unconstrained optimization has been mainly devoted to the definition of new methods for solving large scale problems. In the framework of Newton–Krylov methods, new Conjugate Gradient–type schemes have been introduced to efficiently tackle indefinite problems in the large scale setting [9, 8]. Moreover, nonmonotone schemes have been further developed for defining both derivative–free iterative algorithms for the solution of large systems of nonlinear equations and Gauss–Newton methods for large scale nonlinear least–squares problems [10, 1].

Constrained Optimization Problems with a particular structure have been addressed, focusing on linearly constrained problems. In particular, a new derivative–free globally convergent algorithm for linearly constrained finite minimax problems has been defined by means of a smoothing technique based on an exponential penalty function [2]. Problems with a single linear equality constraint and box constraints have been also studied. In this case a decomposition algorithm has been used by employing, at each iteration, a descent direction selected among a suitable set of sparse feasible directions [12].

The problem of training Support Vector Machines represented another topic of interest. It is a linearly constrained convex quadratic problems where the dimension is usually so large that standard methods are not reliable. Hence, a hybrid decomposition algorithm model which at each iteration operates only on a small subset of variables has been proposed [13].
Finally, a significant selection of the most relevant developments in nonlinear optimization has been collected in the volume [3].

Equilibrium problems Another topic of interest was the study of Generalized Nash Equilibrium Problems (GNEP). GNEPs are a variant of the usual Nash Equilibirum Problem wherein the feasible sets of the players depend on the other players' strategies. In [7] the reduction of a GNEP to a variational inequality was considered. Moreover, a GNEP model for the QoS routing in tlc networks is proposed in [6].

Global Optimization Globally convergent modifications of the algorithm Particle Swarm Optimization (PSO) for the solution of global optimization problems have been developed. Moreover, new properties of the sequence of the iterates are proved and exploited to improve the efficiency of the resulting method. The numerical experiences performed confirmed the effectiveness of the method [5, 4].

Applications An important aspect of the research was the definition of optimization algorithms for solving problems arising from real world applications. In particular, an application arising in sensor network localization with anchors and noisy distance information has been considered. A robust primal–dual interior–point algorithm for a semidefinite programming relaxation for sensor localization has been derived [11].

Journals

[1] G. Fasano, F. Lampariello, and M. Sciandrone. A truncated nonmonotone Gauss-Newton method for large-scale nonlinear least-squares problems. *Computational Optimization and Applications*, 34:343–358, 2006.

[2] G. Liuzzi, S. Lucidi, and M. Sciandrone. A derivative–free algorihms for linearly constrained finite minimax problems. *SIAM Journal on Optimization*, 16:1054–1075, 2006.

Book

[3] G. Di Pillo and M. Roma, editors. *Large–Scale Nonlinear Optimization*, volume 83 of *Nonconvex Optimization and its Applications*. Springer, 2006.

Conference proceedings

[4] E.F. Campana, G. Fasano, D. Peri, and A. Pinto. Dynamic system analysis and initial particles position in particle swarm optimization. In *Proceedings of the IEEE Swarm Intelligence Symposium*, 2006.

[5] E.F. Campana, G. Fasano, D. Peri, and A. Pinto. Particle swarm optimization: efficient globally convergent modifications. In *Proceedings of the III European Conference on Computational Mechanics – Solids, Structures and Coupled Problems in Engineering*, 2006.

Submitted papers, technical reports and others

[6] P. Conforto, F. Delli Priscoli, and F. Facchinei. A non–cooperative game for QoS routing: properties of the Nash equilibrium point. Submitted to *Automatica*.

[7] F. Facchinei, A. Fischer, and V. Piccialli. On generalized Nash games and variational inequalities. To appear in *Operations Research Letters*.

[8] G. Fasano. Lanczos–Conjugate Gradient method and pseudoinverse computation on indefinite and singular systems. To appear in *Journal on Optimization Theory and Applications*.

[9] G. Fasano and M. Roma. Iterative computation of negative curvature directions in large scale unconstrained optimization. To appear in *Computational Optimization and Applications*.

[10] L. Grippo and M. Sciandrone. Nonmonotone derivative-free methods for nonlinear equations. To appear in *Computational Optimization and Applications*.

[11] N. Krislock, V. Piccialli, and H. Wolkowicz. Robust semidefinite programming approaches for sensor network localization with anchors. Submitted to *Journal of Combinatorial Optimization*.

[12] C.-J. Lin, S. Lucidi, L. Palagi, A. Risi, and M. Sciandrone. A decomposition algorithm model for singly linearly constrained problems subject to lower and upper bounds. Submitted to *Journal on Optimization Theory and Applications*.

[13] S. Lucidi, L. Palagi, A. Risi, and M. Sciandrone. On the convergence of hybrid decomposition methods for SVM training. Technical Report 06–2006, Dipartimento di Informatica e Sistemistica "A. Ruberti", Università di Roma "La Sapienza", 2006. Submitted to *IEEE Transactions on Neural Networks*.

Finito di stampare nel mese di aprile del 2007
dalla tipografia « Braille Gamma S.r.l. » di Santa Rufina di Cittaducale (Ri)
per conto della « Aracne editrice S.r.l. » di Roma

CARTE

Copertina: *Digit Linen* 270 g/mq
Interno: *Usomano bianco Selena* 80 g/mq
Allestimento: legatura a filo di refe / brossura

Printed in Italy