

Sonia Cafieri

Place and date of birth: Naples, Italy, July 4, 1979
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Main research interests

- Reformulation techniques in mathematical programming.
- Global optimization.
- Combinatorial optimization.
- Network clustering.
- Interior point algorithms for nonlinear programming.
- Numerical linear algebra in constrained optimization.

Education

- *2009*: On the French National University Council (CNU) **qualification** lists for “Maître de Conférences” in section 26 (applied mathematics) and 27 (computer science).
- *Jan 2006*: **Ph.D. in Mathematical Sciences**,
Thesis title: *On the application of iterative solvers to KKT systems in Interior Point methods for Large-Scale Quadratic Programming problems.*
Awarded by: University of Naples “Federico II”, Italy.
Awarded on: 10th January 2006.
Supervisor: Prof. M. D’Apuzzo.
Jury: Prof. M. Marino, Prof. D. Giachetti, Prof. M. Lapegna.
- *Oct 2001*: **Master in Mathematics**,
110/110 cum Laude
Thesis title: *Quadratic Optimization: Algorithms and Software for sparse problems.*
Awarded by: Second University of Naples, Italy.
Awarded on: 30th October 2001.
Supervisor: Prof. M. D’Apuzzo.

Employment History

- *Dec 2009 - present*
Assistant Professor
École Nationale de l'Aviation Civile, France.
- *Mar 2008 - Nov 2009*
Post-doc Researcher
Laboratoire d'Informatique (LIX), École Polytechnique, France.
Topic: Reformulation techniques in Mathematical Programming.
Research advisor: Dr. L. Liberti.
- *Jun 2007 - Feb 2008*
Post-doc Researcher
Interdipartimental Research Center Bioagromed, University of Foggia, Italy.
Topic: PDE-based mathematical models for food science applications.
Research advisor: Prof. M.A. Del Nobile.
- *Apr 2007 - May 2007*
Research Fellow
Department of Mathematics, Second University of Naples, Italy.
Topic: Application of optimization algorithms and software to bioinformatics.
Research advisor: Prof. M. D'Apuzzo.
- *Sep 2006 - Nov 2006*
Research Fellow
Department of Mathematics, Second University of Naples, Italy.
Topic: Development of software tools for Quadratic Programming.
Research advisor: Prof. M. D'Apuzzo.
- *Jun 2001 - Sep 2001*
Stage at Center for Research on Parallel Computing and Supercomputers - CPS/CNR, nowadays
Institute for High Performance Computing and Networking - ICAR/CNR - Naples branch.
Topic: Algorithms and software for high performance computing.

Research Activity

- *Reformulation techniques in Mathematical Programming and Global Optimization.* This is the main topic of my research activity as post-doc at École Polytechnique, within the context of the ANR-funded project *ARS* on reformulations. A reformulation of a mathematical program P is a mathematical program Q obtained from P via symbolic transformations applied to the set of variables, objective and constraints. Reformulation techniques are often used to re-cast a particular type of problem into a formulation which is amenable to be solved by a given algorithm. The research line is devoted to the investigation of new reformulation techniques, to the formalization and implementation of solution algorithms based on such techniques and to the development of software tools for automating mathematical programming reformulation. The final aim of this research is to develop a software

able to automatically reformulate optimization problems and solve it by using one of the implemented methods. Software: ROSE-Reformulation/Optimization Software Engine (co-developer).

A reformulation is a relaxation if one or more constraints are eliminated. These reformulations are useful because provide a bound on the objective function value at the optimum. Such bounds are mainly used in Branch and Bound based global optimization methods, that work recursively partitioning the search space and computing a lower and an upper bound to the optimal value of the objective function in each subregion. In particular, different convex relaxations for quadrilinear terms, based on the idea of exploiting bilinear and trilinear convex envelopes, are currently under investigation in order to determine the tightest.

- *Network Clustering.* Network clustering is a powerful tool for the automatic analysis of complex systems, with applications in many areas, such as natural sciences, sociology, medicine, engineering, marketing. A topic of particular interest in the study of complex networks is the identification of communities, also called modules or clusters. Given a network (or graph) $G = (V, E)$ with a vertex set V and an edge set E , a community is a subset of vertices such that there are more edges within the community than edges joining it to the outside. A clustering criterion is chosen, in terms of presence or absence of edges. A mathematical programming problem can be formulated corresponding to such a criterion, usually a combinatorial problem. The research line concerns criteria for the identification of communities and hierarchical as well as partitioning algorithms to detect communities in complex networks.
- *Interior Point algorithms for nonlinear programming.* Interior Point algorithms for nonlinear programming represent the main research line during my Ph.D. and the first stage of my post-doc activity. Interior Point methods are effective and widely used methods for nonlinear programming problems. The focus is mainly on large-scale convex Quadratic Programming and related numerical Linear Algebra issues. In particular, I investigated the Interior Point Potential Reduction method. My research activity concerned the re-examination of the global convergence properties of such method in order to take into account an inexact solution of the inner linear KKT systems. The final product of this research activity is a software package for quadratic programming. Software: PRQP - Potential Reduction Software for Quadratic Programming (soon available).
- *Numerical Linear Algebra in constrained optimization.* A crucial issue in the effective solution of optimization problems with Interior Point methods is the availability of efficient and robust computational linear algebra kernels, especially for the solution of the linear KKT system that arises at each iteration of the method. In this context, the research activity has been mainly aimed to the development, the analysis and the implementation of iterative methods for the efficient solution of the KKT systems arising at each iteration of Interior Point methods for large-scale quadratic programming problems. Approaches based on a Constraint Preconditioner and an Incomplete Cholesky factorization coupled with Krylov solvers have been analyzed, in a Potential Reduction (PR) framework. Adaptive stopping criteria for the inner iterations have been developed, that relate the accuracy in the solution of the KKT system to the quality of the current PR iterate, to increase the overall computational efficiency. Moreover, we proposed an approximation strategy for the constraint preconditioner, with the aim of reducing the cost of the preconditioner application. Numerical experiments show that this approach is effective in reducing the computational cost. The above methods have been implemented and tested within the PRQP software.

Organization Activities

- Scientific and local organizing committee member in Toulouse Global Optimization workshop (TOGO10) in Toulouse, France, September 2010.
- Local organizing committee member in CTW09 international workshop on Graphs and Combinatorial Optimization in Paris, France, June 2009. Co-editor of the Conference Proceedings.
- Referee for: Journal Of Global Optimization, Optimization Letters, Computational Optimization and Applications, Journal Of Control, Journal of Computer Mathematics, Information Processing Letters.
- Participation in scientific projects:
 - 2005- 2007
Innovative Problems and Methods in Nonlinear Optimization, PRIN Project, funded by Italian Ministry of University and Research (MIUR).
 - 2003- 2006
Large Scale Nonlinear Optimization, FIRB Project, funded by Italian MIUR.
- Presentation of the organization of undergraduated courses of the Second University of Naples.

Conferences and Workshops with contributed talks

- ISMP09 - The 20th International Symposium of Mathematical Programming, Chicago, USA, August 2009.
Talk title: “Comparing convex relaxations of quadrilinear terms”.
- WCGO09 - World Congress on Global Optimization in Engineering and Science, Hunan, China, June 2009.
- CIMINLP - Computational Issues in MINLP, Bordeaux, March 19-20, 2009 (**Invited speaker**).
- ROADEF09, Nancy, France, Feb 10-12 2009.
Talk title: “Convex relaxations for quadrilinear terms”.
- ARS08 - first ANR Automatic Reformulation Search Project Workshop, École Polytechnique, Palaiseau, France, Oct 31st 2008.
Talk titles: “Rose: Reformulation/Optimization Software Engine”; “Convex relaxations for quadrilinear terms”.
- Journée Optimeo, Versailles, France, June 11 2008.
Talk title: “Linear Algebra issues in Interior Point solvers for Quadratic Programming”.
- IMA Conference on Numerical Linear Algebra and Optimisation, Birmingham, UK, Sept 13-15 2007.
Talk title: “Approximate Constraint Preconditioners for KKT Systems arising in Interior Point Methods”.
- Concluding conference of the Italian MIUR FIRB project “Large Scale Nonlinear Optimization”, Capri, Italy, Apr 19-20 2007.
Talk title: “Sviluppo di software Interior Point per problemi di Ottimizzazione Quadratica”.

- SIMAI06 - 8th Congress of the Italian Society for Applied and Industrial Mathematics, Ragusa, Italy, May 22-26 2006.
Talk title: “On the use of Constraint Preconditioners in Potential Reduction methods”.
- IFIP TC 7 Conference on System Modeling and Optimization, Torino, Italy, July 18-22 2005.
Talk title: “A Potential Reduction Solver for Large-Scale Quadratic Programming Problems”.
- AIRO04 - 35th Annual Conference of the Italian Operations Research Society, Lecce, Italy, Sept 7-10 2004.
Talk title: “On Linear Algebra Solvers in Potential Reduction Software for Large Scale Quadratic Problems”.
- Large Scale Nonlinear Optimization, Erice, Italy, June 22-July 1 2004.
Talk title: “Linear Algebra Issues in Developing Potential Reduction Software for Large Scale Quadratic Programs”.
- Numerical Methods for Local and Global Optimization: Sequential and Parallel Algorithms, Cortona, Italy, July 14-20 2003.
Talk title: “An Interior Point Solver for Large-Scale Quadratic Programs”.

Visiting terms and seminars

- GERAD, HEC Montréal. 2009 (1 month) visiting researcher. 1 seminar. Invited by P. Hansen.
- LRI, Université Paris XI. 2009, 1 seminar, invited by A. Lissier.
- Lamsade, Université Paris Dauphine. 2009, 1 seminar, invited by R. Mahjoub.
- Center for Applied Optimization, University of Florida, Gainesville. 2007 (3 weeks), visiting scholar. 1 seminar. Invited by P.M. Pardalos.

Teaching experience

Note: Some didactic material for the courses can be downloaded from <http://www.lix.polytechnique.fr/~cafieri>

- **Operations Research: Modelling and Software** (in French “Recherche Operationelle: Modélisation et Utilisation logiciel”). Given 2 times at École Polytechnique, as assistant to Prof. L. Liberti. *Syllabus:* the language of mathematical programming, choice of solution algorithms, basic reformulations, complex applications. The course was taught as assistant in the academic years 2008/09 and 2009/2010, in the first semester. Approximately 15 students, 2 hours of lectures, 16 hours of computer labs. Course level: M.Sc.
- **Introduction to C++**. Given 1 time at École Polytechnique. The course was taught as assistant in the academic year 2009/2010, in the first semester. Approximately 25 students, 6 hours of computer labs. Course level: M.Sc.

- **Informatics** (in Italian, “Informatica”). Given 1 time at the Second University of Naples, for the Course in *Biology*, as teacher. *Syllabus*: fundamentals of computer organization and architecture, introduction to the development of algorithms, use of Microsoft Office and basic use of Matlab for visualization and analysis of biological data. The course was taught the academic year 2005/06, in the second semester. Approximately 300 students, 40 hours of lectures, 20 hours of computer labs. Course level: B.Sc.
- **Informatics** (in Italian, “Informatica”). Given 3 times at the Second University of Naples, for the Course in *Biology*, as assistant. *Syllabus*: fundamentals of computer organization and architecture, introduction to the development of algorithms, use of Microsoft Office and basic use of Matlab for visualization and analysis of biological data. Course level: B.Sc.
 - II semester 2002-2003. Assistant to Prof. D. Romano. 200 students. Computer labs: 50 hours.
 - II semester 2003-2004. Assistant to Prof. M. D’Apuzzo. 300 students. Computer labs: 50 hours. Lectures: 10 hours.
 - II semester 2004-2005. Assistant to Prof. M. D’Apuzzo. 300 students. Computer labs: 50 hours. Lectures: 14 hours.
- **Introduction to Numerical Methods for Optimization** (in Italian, “Elementi di metodi numerici per l’ottimizzazione”). Given 1 time at the Second University of Naples, for the Courses in *Mathematics* and *Mathematics and Informatics*, as assistant to Prof. M. D’Apuzzo and D. di Serafino. *Syllabus*: methods for solving unconstrained optimization problems. The course was taught as assistant in the academic year 2005/06 in the second semester. Approximately 10 students, 8 hours of lectures. Course level: M.Sc.
- **Parallel Computing** (in Italian, “Calcolo Parallelo”). Given 4 times at the Second University of Naples, for the Courses in *Mathematics* and *Mathematics and Informatics*, as assistant to Prof. M. D’Apuzzo and D. di Serafino. *Syllabus*: methods and strategies for developing parallel software procedures for MIMD computers. The course was taught as assistant every academic year, from 2002/03 to 2005/06, in the first semester. Approximately for every year: 20 students, 10 hours of computer labs and 10 hours of lectures. Course level: B.Sc.
- **Numerical Computations** (in Italian, “Calcolo Numerico”). Given 4 times at the Second University of Naples, for the Courses in *Mathematics* and *Mathematics and Informatics*, as assistant to Prof. M. D’Apuzzo and D. di Serafino. *Syllabus*: solution of linear systems by direct and iterative methods, data representation and interpolation, quadrature formulas, the C programming language. The course was taught as assistant every academic year, from 2002/03 to 2005/06, in the second semester. Approximately for every year: 50 students, 20 hours of computer labs and 10 hours of lectures. Course level: B.Sc.
- **Introduction to Programming** (in Italian, “Laboratorio di Programmazione e Calcolo”). Given 4 times at the Second University of Naples, for the Courses in *Mathematics* and *Mathematics and Informatics*, as assistant to Prof. M. D’Apuzzo, D. di Serafino and V. De Simone. *Syllabus*: floating-point arithmetic, round-off errors and basic matrix computation. The course was taught as assistant every academic year, from 2002/03 to 2005/06, in the second semester. Approximately for every year: 100 students, 20 hours of computer labs and 10 hours of lectures. Course level: B.Sc.

- **Introduction to Informatics** (in Italian, “Laboratorio di Programmazione”). Given 4 times at the Second University of Naples, for the Courses in *Mathematics* and *Mathematics and Informatics*, as assistant to Prof. M. D’Apuzzo, D. di Serafino and V. De Simone. *Syllabus*: basic informatics concepts and introduction to Fortran. The course was taught as assistant every academic year, from 2002/03 to 2005/06, in the first semester. Approximately for every year: 100 students, 20 hours of computer labs and 10 hours of lectures. Course level: B.Sc.
- **Introduction to HTML**. Mini-course of 8 hours. Given 3 times at the Second University of Naples. *Syllabus*: introduction to the development of simple web pages by HTML. The mini-course was taught as teacher the academic years 2003/04, 2004/05 and 2005/2006. Approximately 20 students.
- **Computational Mathematics** (in Italian, “Matematica Computazionale”). Given 2 times at the Second University of Naples, for the Courses in *Mathematics*, as assistant to Prof. M. D’Apuzzo and D. di Serafino. *Syllabus*: methods and strategies for developing parallel software procedures for MIMD computers. The course was taught as assistant in the academic years 2002/03 and 2003/04, in the first semester. Approximately for every year: 20 students, 10 hours of computer labs and 10 hours of lectures. Course level: M.Sc.
- **Programming and Numerical Computations** (in Italian, “Calcolo Numerico e Programmazione”). Given 2 times at the Second University of Naples, for the Courses in *Mathematics*, as assistant to Prof. M. D’Apuzzo and D. di Serafino. *Syllabus*: data representation, interpolation, quadrature formulas, direct and iterative methods for linear systems, solution of nonlinear equations, the C programming language, introduction to Matlab. The course was taught as assistant every academic years 2002/03 and 2003/04, in the second semester. Approximately for every year: 30 students, 10 hours of computer labs and 6 hours of lectures. Course level: M.Sc.
- **Numerical Analysis** (in Italian, “Analisi Numerica”). Given 3 times at the Second University of Naples, for the Courses in *Mathematics*, as assistant to Prof. M. D’Apuzzo and D. di Serafino. *Syllabus*: computer architecture, floating-point arithmetic, round-off errors, basic linear algebra and introduction to Fortran. The course was taught as assistant every academic year, from 2002/03 to 2004/05, in the first semester. Approximately for every year: 30 students, 10 hours of computer labs and 6 hours of lectures. Course level: M.Sc.

Supervising and tutoring

- 2006: Co-supervision (with M. D’Apuzzo) of the M.Sc. thesis of A. Aldanese. Second University of Naples. Topic: Software for linear programming problems.
- 2006: Co-supervision (with D. di Serafino) of the M.Sc. thesis of E. Giannelevigna. Second University of Naples. Topic: A Potential Reduction method for quadratic optimization.
- 2004: Co-supervision (with M. D’Apuzzo) of the M.Sc. thesis of L. Minicucci. Second University of Naples. Topic: Interior Point methods for quadratic optimization.
- Personal tutor for students of Second University of Naples every academic year from 2003/2004 to 2005/2006.

Computer-related skills

- Programming Languages: C, C++, Fortran77/90, Perl, Matlab.
- Operating Systems: Unix, Linux, Windows.
- Linear Algebra Packages: BLAS, LAPACK, ICFS, HSL.
- Optimization Systems and Software: KNITRO, MOSEK, LANCELOT, CPLEX, AMPL, SNOPT and others, both commercial and free.
- Parallel Computing Packages: MPI, SCALAPACK.

Developed Software

- PRQP (Potential Reduction for Quadratic Programming)
solves convex quadratic problems with linear constraints
 - primal-dual infeasible PR method, feasible whenever possible;
 - different solvers for the KKT system: direct, CG, SQMR;
 - exact and reused constraint preconditioner, limited-memory ICF for bound constrained problems;
 - MA27 routine by the HSL library for sparse LDL^T computation;
 - custom SQMR and sparse matrix-vector products;
 - AMPL and SIF interfaces;
 - Fortran77, C drivers.
- PR-BCQP
solves convex quadratic problems with only bounds on the variables; it is currently part of PRQP, but can be used as stand-alone software.
- ROSE (Reformulation/Optimization Software Engine)
software framework for automatic reformulations of mathematical programming problems. Contribution to the code development – work in progress.
 - reformulators able to automatically provide convex relaxations of non-convex nonlinear problems;
 - wrappers to external numerical local solvers (IPOPT).

Languages

- Italian: mother tongue.
- English: good spoken and written.
- French: intermediate level of knowledge.

Publications

- International Journals

1. **S. Cafieri**, P. Hansen, L. Liberti, *Edge ratio and community structure in networks*, Les Cahiers du GERAD, G-2009-55, submitted for publication.
2. **S. Cafieri**, J. Lee, L. Liberti, *On convex relaxations of quadrilinear terms*, Journal of Global Optimization, DOI 10.1007/s10898-009-9484-1, 2009.
3. **S. Cafieri**, S. Chillo, M. Mastromatteo, N. Suriano, M.A. Del Nobile, *A mathematical model to predict the effect of shape on pasta hydration kinetic during cooking and overcooking*, Journal of Cereal Science, 48 (3): 857–862, 2008.
4. **S. Cafieri**, M. D’Apuzzo, V. De Simone, D. di Serafino, G. Toraldo, *Convergence Analysis of an Inexact Potential Reduction Method for Convex Quadratic Programming*, Journal of Optimization Theory and Applications, 135: 355–366, 2007.
5. **S. Cafieri**, M. D’Apuzzo, V. De Simone, D. di Serafino, *Stopping criteria for inner iterations in inexact Potential Reduction methods: a computational study*, Computational Optimization and Applications, special issue on Linear Algebra issues arising in Interior Point methods, J. Gondzio and G. Toraldo eds., 36 (2): 165–193, 2007.
6. **S. Cafieri**, M. D’Apuzzo, V. De Simone, D. di Serafino, *On the Iterative Solution of KKT Systems in Potential Reduction Software for Large Scale Quadratic Problems*, Computational Optimization and Applications, special issue on High Performance Algorithms and Software for Nonlinear Optimization, A. Murli and G. Toraldo eds, 38: 27–45, 2007.
7. **S. Cafieri**, M. D’Apuzzo, M. Marino, A. Mucherino, G. Toraldo, *Interior Point Solver for Large-Scale Quadratic Programming Problems with Bound Constraints*, Journal of Optimization Theory and Applications, 129 (1): 55–75, 2006.

- Books edited

8. **S. Cafieri**, A. Mucherino, G. Nannicini, F. Tarissan, L. Liberti (eds.), *Proceedings of CTW09 Conference on Graphs and Combinatorial Optimization*, Paris, 2009.

- Book chapters (refereed)

9. L. Liberti, **S. Cafieri**, F. Tarissan, *Reformulations in Mathematical Programming: a Computational Approach*, in A. Abraham, A.-E. Hassanien, P. Siarry, and A. Engelbrecht (eds.), Foundations of Computational Intelligence Vol. 3 (Global Optimization: Theoretical Foundations and Applications), Studies in Computational Intelligence, 203:153-234, Springer, Berlin, 2009.

- Conferences (refereed)

10. **S. Cafieri**, J. Lee, L. Liberti, *Comparison of convex relaxations of quadrilinear terms*, in C. Ma, L. Yu, D. Zhang, Z. Zhou (eds.), Global Optimization: Theory, Methods and Applications I, Lecture Notes in Decision Sciences, 12(B):999-1005, Global-Link Publishers, Hong Kong 2009.
11. **S. Cafieri**, J. Lee, L. Liberti, *Convex relaxations for quadrilinear terms*, Proceedings of ROADEF 09, 2009.

12. **S. Cafieri**, P. Hansen, L. Liberti, *Reformulations between structured global optimization problems and algorithms*, Proceedings of ROADEF 09, 2009.
 13. **S. Cafieri**, M. D'Apuzzo, V. De Simone, D. di Serafino, *On the Use of an Approximate Constraint Preconditioner in a Potential Reduction Algorithm for Quadratic Programming*, in V. Cutello, G. Fotia and L. Puccio (eds.), Applied and Industrial Mathematics in Italy II, Series on Advances in Mathematics for Applied Sciences Vol. 75, World Scientific, 2007.
- Theses
 14. **S. Cafieri**, *On the application of iterative solvers to KKT systems in Interior Point methods for Large-Scale Quadratic Programming problems*, Ph.D. Thesis, University of Naples "Federico II", 2006.
 15. **S. Cafieri**, *Ottimizzazione quadratica: algoritmi e software per problemi sparsi* (in Italian), Tesi di Laurea, Second University of Naples, 2001.