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#### Education

Mar '03: Dept. of Electronics and Computer Science, Politecnico di Milano, Italy  
Ph.D. in Computer Engineering  
Thesis: "Multicommodity network design with survivability constraints: models and algorithms"  
Advisor: Prof. Federico Malucelli  
Apr '99: Dept. of Electronics and Computer Science, Politecnico di Milano, Italy  
M.Sc. in Computer Engineering (mark: 100/100)  
Thesis: "The obnoxious  $p$ -median problem: exact and heuristic algorithms"  
Advisor: Prof. Francesco Maffioli

#### Research interests

**Mixed Integer Nonlinear Programming (MINLP):** exact methods for the solution of practical non-convex problems arising in a number of fields, including Chemical Engineering, Portfolio Optimization, and water treatment.

- A spatial branch&bound technique for non-convex MINLPs: bound tightening and convexification approaches to obtain lower bounds.
- Exact solution methods for Mixed Integer Conic Programming problems.
- Exact approaches for Mixed Integer Quadratic Problems (MIQP).
- Linear Programming relaxations of Quadratic Problems.

**Multicommodity network flow problems:** exact and heuristic methods for network design problems arising in Telecommunications.

- Network design with stepwise node costs: valid inequalities and a branch&cut method.
- *Shared Protection* network design: valid inequalities and a decomposition approach.
- Multi-layer network design: row-column generation; decomposition approaches.
- Branch&price for network design with uncertainty in the traffic matrix.
- Branch&cut for network design with probabilistic traffic demands.

**The Maximum Feasible Subsystem (MAXFS) problem:** randomized, thermal relaxation methods for the problem of finding, in an infeasible linear system, a feasible subsystem with as many inequalities as possible. Tests with a parallel version on the IBM BlueGene/L supercomputer to solve large instances (up to 18 millions of constraints) of MAXFS arising in fields such as Machine Learning, Telecommunications, and Computational Biology.

Other interests include: valid inequalities for obnoxious location problems; non-linear formulations for Sphere packing problems in  $n$  dimensions.

## Positions

- Aug '08 – present: Visiting Assistant Professor, Dept. of Industrial & Systems Engineering, Lehigh University, Bethlehem, PA.
- Oct '06 – Jul '08: Postdoctoral Fellow, Tepper School of Business, Carnegie Mellon University, Pittsburgh, PA.
- Apr '03 – Aug '06: FIRB Postdoctoral Fellow, Dept. of Electronics and Computer Science, Politecnico di Milano, Italy.

## Awards

- June 2009: Best paper award: G. Panza, A. Capone, D. Pinarello and P. Belotti. "Robustness in Next-Generation Networks", ICT Summit Europe.

## Teaching

- Spring 2009: "IE341 – Data communication systems analysis and design" (undergrad.), Lehigh University. Syllabus: design, simulation, and technological aspects of Local, Metropolitan, Wide-area, and distributed computing networks.
- Spring 2009: "IE172 – Algorithms for systems engineering" (undergrad.), Lehigh University. Syllabus: Design, analysis, and implementation of algorithms for common engineering applications. Sorting and searching, graph algorithms, algorithms for numerical applications.
- Fall '08, '09: "IE426 – Optimization models and applications" (graduate), Lehigh University. Syllabus: convexity and relaxation; models in Linear Programming, Integer Programming, Stochastic Programming, and Nonlinear Programming. Case studies with hands-on experience on real-world problems.
- 2006: Section classes, "C++ for Java users", LIX, École Polytechnique, Paris, France.
- 2004-2005: Co-lecturer, "Design of telecommunication networks," Telecommunications Engineering, Politecnico di Milano, Italy. Syllabus: Models for uncapacitated and capacitated network design problems. Solution techniques: cutting planes, column generation, Lagrangean Relaxation, heuristics. Case studies of synthesis of real-world networks.
- 2005: Lecturer, "Introduction to Operations Research," Computer Engineering, Politecnico di Milano, Italy. Syllabus: Graph Theory, flow problems, Linear Programming, Mixed Integer Linear Programming. Complexity theory, heuristic and approximation algorithms.
- 2000-2001: Section classes, "Operations Research," Computer Engineering, Politecnico di Milano, Italy. Lecturer: F. Maffioli.
- 2001-2004: Section classes, "Introduction to Operations Research," Computer Engineering, Politecnico di Milano. Lecturers: F. Maffioli, F. Malucelli, N. Maculan.
- 2000-2001: Instructor, UNIX system programming, C, and C++, EU-funded Computer Science courses, Bergamo, Italy (60 hours).
- 2000-2001: Instructor, UNIX C and C++, *SpazioZeroUno* Computer Science courses, Vimercate, Milan, Italy (80 hours).

## Grants awarded

- 2009: Co-P.I., "Computational Models And Algorithms For Enterprise-Wide Optimization Of Process Industries," PITA – Pennsylvania Infrastructure Technology Alliance. \$19,250, with L.V. Snyder.

- 2009: Co-P.I., "Capacity Planning For A Gases Supply Chain With Network Disruptions And Interruptible Power," PITA – Pennsylvania Infrastructure Technology Alliance. \$33,000, with L.V. Snyder.
- 2005: Short Term Scientific Mission at ZIB Institute, Berlin, on the design of multi-layer networks, within the "GRAAL" (GRAphs and ALgorithms in communication networks) COST Action 293 of the European Community.
- 2003-2004: Grant MISAG-CNR-1 jointly from TUBITAK, The Scientific and Technological Research Institution of Turkey, and the Italian Research Council, on the project "Optimization of telecommunications networks under uncertainty".
- 2001: Research grant on "Optimization models for optical network design", Ericsson ONER Laboratory, Stockholm, and Linköping Universitet, Sweden.

#### Short visits

- 2005-08: Short visits at IBM T.J. Watson Research Center, Yorktown Heights, NY. Testing a parallel relaxation method on the BlueGene/L supercomputer (with L. Ladányi and J. Lee). Development of an exact solver for non-convex MINLP (with J. Lee, P. Bonami, A. Wächter).
- Sep '06: Laboratoire d'Informatique (LIX), École Polytechnique, Paris, with Leo Liberti. Exact algorithms for non-convex mixed integer nonlinear programming (MINLP) problems.
- Mar-Jun '06: Dept. of System Engineering, Università di Roma "Tor Vergata", with G. Oriolo and L. Sanità. Exact and approximation algorithms for network design problems under uncertainty.
- Nov '05: Optimization Group, ZIB Institute, Berlin, Germany, with S. Orlowski and R. Wessäly. Exact algorithms for multi-layer network design problems: branching rules, cutting planes, decomposition approaches.
- Oct '03, Oct '04: Dept. of Industrial Engineering, Bilkent University, Ankara, Turkey, with M. Pınar and A. Altın. Exact algorithms for the design and management of network under uncertainty in the traffic demand.
- Feb – Mar '01: Dept. of Applied Mathematics, Linköpings Universitet, Sweden, with D. Yuan and P. Värbrand. Algorithms for network design with step-wise linear costs on the network nodes.
- Jan – Feb '01: Ericsson Optical Networking Laboratory, Stockholm, Sweden. Evaluation of commercial and academic software for network design.

#### Publications

##### *Journals*

- P. Belotti, J. Lee, L. Liberti, F. Margot, A. Wächter, Branching and bounds tightening techniques for nonconvex MINLP. *Optimization Methods & Software* 24(4-5):597-634, 2009.
- A. Altın, P. Belotti, and M.Ç. Pınar, "OSPF Routing with Optimal Oblivious Performance Ratio Under Polyhedral Demand Uncertainty." To appear, *Optimization and Engineering*, 2009. (pdf)
- P. Belotti, M.Ç. Pınar, "Optimal oblivious routing under statistical uncertainty," *Optimization and Engineering* 9(3):257-271, 2008.
- P. Belotti, A. Capone, G. Carello, F. Malucelli, "Multi-layer MPLS Network Design: the Impact of Statistical Multiplexing," *Computer Networks* 52 (6), pp. 1125-1342, 2008.

A. Altın, E. Amaldi, P. Belotti, M.Ç. Pınar, "Provisioning virtual private networks under traffic uncertainty," *Networks* 49 (1):90-99, 2007.

P. Belotti, L. Brunetta, F. Malucelli, "Multicommodity network design with discrete node costs," *Networks* 49 (1):100-115, 2007.

P. Belotti, S. Kucherenko, L. Liberti, N. Maculan, "New formulations for the Kissing Number Problem," *Discrete Applied Mathematics* 155 (14):1837-1841, 2007.

E. Amaldi, P. Belotti, A. Capone, F. Malucelli, "Optimizing base station location and configuration in UMTS networks," *Annals of Oper. Res.* 146 (1):135-151, 2006.

P. Belotti, M. Labbé, F. Maffioli, M. Ndiaye, "A branch-and-cut method for the Obnoxious  $p$ -Median problem", *4OR* 5 (4):299-314, 2007.

P. Belotti, "Multicommodity network design with survivability constraints: some models and algorithms," *4OR* 3 (1):79-81, 2005.

#### *Book Chapters*

A.M.C.A. Koster, S. Orłowski, C. Raack, G. Baier, T. Engel, P. Belotti, "Branch-and-cut techniques for solving realistic two-layer network design problems". In A.M.C.A. Koster, Xavier Muñoz (eds.), *Graphs and Algorithms in Communication Networks*, Springer-Verlag, 2009.

#### *International conference proceedings*

G. Panza A. Capone, D. Pinarello, P. Belotti, Robustness in Next-Generation Networks, ICT Summit Europe 2009, Santander, Spain.

E. Amaldi, P. Belotti, R. Hauser, "Randomized relaxation methods for the maximum feasible subsystem problem". Proceedings, IPCO XI, Berlin 2005. *Lecture Notes in Computer Science* 3509:249-264, 2005.

P. Belotti, A. Capone, G. Carello, F. Malucelli, F. Senaldi, A. Totaro, Design of Multi-layer networks with traffic grooming and statistical multiplexing 3rd International Network Optimization Conference (INOC 2007), Spa, Belgium.

P. Belotti, A.M.C.A. Koster, S. Orłowski, A cut&branch&price approach to two-layer network design, The 8th INFORMS Telecommunications Conference, Dallas TX 2006.

P. Belotti, C. Spinelli, E. Pedrinelli, M. Fumagalli, V. Mascolo, "Evolution of traffic demand and dimensioning a metro-regional transport network", *Fotonica* 2005 (invited).

P. Belotti, F. Malucelli, "Row-column generation for multilayer network design", *INOC 2005*, Lisbon, Portugal, 22-24 March 2005.

P. Belotti, F. Malucelli, "Network design with grooming constraints". *CTW '04*, June 2004, Menaggio, Italy. *Electronic Notes in Discrete Mathematics* 17 (C):51-56, 2004.

A. Altın, E. Amaldi, P. Belotti, M. Pınar, "Provisioning Virtual Private Networks under Traffic Uncertainty." *CTW '04*, June 2004, Menaggio, Italy. *Electronic Notes in Discrete Mathematics* 17 (C):19-22, 2004.

P. Belotti, F. Malucelli, "Row and column generation for multi-layer network design," *OR 2004*, Tilburg, 1-3 September 2004.

P. Belotti, F. Malucelli, "A Lagrangian Relaxation approach to network design with Shared Protection", *INOC 2003*, Paris-Evry (France).

P. Belotti, T. Stidsen, "Optimal Placement of Wavelength Converting Nodes," *DRCN '01*, Budapest, Hungary, 1-3 October 2001.

M. Labbé, F. Maffioli, M. Ndiaye, P. Belotti, "Obnoxious  $p$ -median problems: valid inequalities and a branch and cut approach", proceedings of ORP<sup>3</sup>, Paris 2001.

#### Submitted

P. Belotti, F. Margot, A. Qualizza, Linear Programming Relaxations of Quadratically Constrained Quadratic Programs. Tepper Working Paper 2009-E20 (2009).

G. Nannicini and P. Belotti, A local branching heuristic for MINLPs, 2009. Available at <http://adsabs.harvard.edu/abs/2008arXiv0812.2188N>.

P. Belotti, Disjunctive cuts for non-convex MINLP. Optimization Online, July 2009. [http://www.optimization-online.org/DB\\_HTML/2009/07/2354.html](http://www.optimization-online.org/DB_HTML/2009/07/2354.html)

#### Organization

MOPTA: Organizing committee, MOPTA — Modeling and OPTimization: Theory and Application, Lehigh University, Bethlehem PA, August 19-21, 2009.

BR-OPT: Chair, BR-OPT: Bound Reduction for Mixed Integer Nonlinear Programming. Organized within the CPAIOR conference, Carnegie Mellon University, Pittsburgh PA, May 27-31, 2009.

IntCP: Organizing committee, IntCP 2009 — Interval analysis, constraint propagation, applications (<http://icwww.epfl.ch/~sam/IntCP09>). Held in conjunction with the 15th International Conference on Principles and Practice of Constraint Programming (CP 2009), September 20-24, 2009.

MINLP: Cyber-infrastructure for Mixed Integer Nonlinear Programming (MINLP) problems (<http://www.minlp.org>). A website for exchange of MINLP instances and discussion forums for modeling and solving real-world MINLP problems.

#### Service activities

2008-09: Technical supervision for the REEF (Reconfigurable Educational Experimental Facility) laboratory for undergraduate students, ISE Dept., Lehigh University.

Since 2008: On the graduate application committee for the ISE Dept., Lehigh University.

Since 2008: Technical editor for *Mathematical Programming Computation* (Springer).

Since 2001: Served as a referee for Operations Research, *Informatics J. on Computing*, *Discrete Applied Mathematics*, *Networks*, *J. of Global Optimization*, *4OR*, *European J. of Operational Research*, *OR Letters*, *Optimization Methods & Software*, *Telecommunication Systems*, *Computer Networks*, and *ESA*.

2000-2006: Supervision, ORLAB – the Operations Research laboratory at the Department of Electronics and Computer Science, Politecnico di Milano.

#### Software developed

COUENNE: A Branch&Bound solver for non-convex, Mixed Integer Nonlinear problems, based on Linearization techniques and released within the Coin-OR framework.

(P)RTR: Parallel randomized thermal relaxation method. Tested on instances with up to 18 million constraints on a BlueGene/L supercomputer.

#### Supervised students

##### Graduate:

- Çağrı Latifoğlu (2009-), Lehigh University: Robust Optimization techniques for Production Planning under uncertainty;

- Alberto Totaro and Federico Senaldi (2005), Politecnico di Milano: Lagrangian Relaxation and heuristic approaches for multi-level network design;
- Sara Parolin (2004), Politecnico di Milano: Column generation for the design of networks under the statistical multiplexing assumption;
- Alessandro Cisco (2003), Politecnico di Milano: Heuristics for multi-level network design.

*Undergraduate* (Dept. of Electronics and Computer Science, Politecnico di Milano, Italy):

- Giulio Cavittelli (2005): Lagrangian Relaxation for the problem of designing a network under survivability constraints.

## Languages

Italian: mother tongue.

English: very good, oral and written.

Portuguese: very good, oral and written.

Spanish: good, oral and written.

## References

### **Jon Lee**

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### **François Margot**

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