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From: Charles Audet, `Charles.Audet@gerad.ca`

To: `technicalreports@afosr.af.mil`

Subject: Final report to Dr. Don Hearn

Grant Title: MESH ADAPTIVE DIRECT SEARCH METHODS FOR
CONSTRAINED NONSMOOTH OPTIMIZATION

Grant number: FA9550-09-1-0160

Reporting Period: December 1, 2010 to November 30, 2011

Summary of accomplished work:

More and more researchers are getting interested in the field of blackbox optimization. 2011 marked the beginning of new research projects and collaborations.

- Sébastien Le Digabel, who developed the AFORS-funded NOMAD software for blackbox optimization was hired as an assistant Professor at the Ecole Polytechnique de Montréal. In 2010-2011 he spend 4 months at IBM Watson Lab working with Andy Conn for the development of quadratic models for our class of methods. He also spent 4 months at the university of Chicago with Robert Gramacy to develop TGP models. Both these types of models are being incorporated into our NOMAD software.

In Mai 2010 Sébastien Le Digabel moved back to Montréal and continues collaborating with the AFOSR-funded research projects.

- Christophe Tribes was hired in July 2011 to take over the development of the NOMAD software. Tribes is from mechanical engineering and

his post-doctoral expertise with real MDO problems complements and strengthens our group. We anticipate that his presence will extend our collaboration circle to mechanical engineering researchers.

- We have initiated a new collaboration with A.D. Pelton from chemical engineering, in which we adapted our optimization tools to interact with thermodynamic and properties databases. This led to two publications in the chemical engineering literature.
- Jordan Ninin visited our lab in 2011 as a post-doctoral researcher. He implemented a dedicated non-convex quadratic augmented Lagrangean solver to be integrated within our NOMAD software when quadratic models are used.
- Weiguang Yang, a PhD student of Allison Marsden at the University of California, San Diego, spent two months in Montreal to develop and explore surrogate-based methods for expensive optimization problems encountered in practice in pediatric cardiac surgery.
- Andrea Ianni, a PhD Student of the Sapienza University of Rome under the supervision of Stefano Lucidi, spent 6 months in our laboratory to refine the way our method constructs poll directions to explore the space of variables. His project led to important modifications that are currently being tested.
- Two summer students, Antoine Mesnard from ISIMA and Emmanuel Bignon from ENSEEINT worked on developing extensions to our NOMAD software.
- Our NOMAD C++ software is available at www.gerad.ca/nomad.
- Audet continues to form highly trained personnel. He currently supervises 5 MSc and 2 PhD students.
- Several papers have appeared in top peer reviewed journals. Our papers combine theoretical results, analysis of the limitations of our methods and numerical results on some real engineering problems.

Personnel Supported:

Faculty: Charles Audet,

Research Staff: Sébastien Le Digabel , Christophe Tribes and Jordan Ninin

Students: Mathilde Peyrega, Alexandre Marty, Kien Dang Cong and Alexandre Marty

Summer interns: Antoine Mesnard and Emmanuel Bignon.

Archival publications published during reporting period:

Published:

1. A.E. Gheribi, C. Audet, S. Le Digabel, E. Blisle, C.W. Bale and A. D. Pelton. Calculating optimal conditions for alloy and process design using thermodynamic and properties databases, the FactSage software and the Mesh Adaptive Direct Search algorithm. CALPHAD: Computer Coupling of Phase Diagrams and Thermochemistry. 36 135-143, 2012.
2. C. Audet and S. Le Digabel. The mesh adaptive direct search algorithm for periodic variables. Pacific Journal of Optimization. 8(1) 103-119, 2012.
3. W. Zghal, C. Audet and G. Savard. A New Multi-Objective Approach for the Portfolio Selection Problem with Skewness. Chapter 12 of Advances in Quantitative Analysis of Finance and Accounting. C.F. Lee (Ed), Airiti Press, 2011.
4. A.E. Gheribi, C. Robelin, S. Le Digabel, C. Audet and A.D. Pelton. Calculating All Local Minima on Liquidus Surfaces Using the FactSage Software and Databases and the Mesh Adaptive Direct Search Algorithm. The Journal of Chemical Thermodynamics. 43(9) 1323-1330, 2011.
5. C. Audet. A short proof on the cardinality of maximal positive bases. Optimization Letters. 5(1) 191-194, 2011.

6. C. Audet, C.-K. Dang and D. Orban. Algorithmic Parameter Optimization of the DFO Method with the OPAL Framework. In *Software Automatic Tuning: From Concepts to State-of-the-Art Results*, K. Naono, K. Teranishi, J. Cavazos, R. Suda, (eds), pages 255-274. Springer. 2010.
7. C. Audet, J.E. Dennis, and S. Le Digabel. Globalization strategies for Mesh Adaptive Direct Search. *Computational Optimization and Applications*. 46(2):193-215, 2010.
8. S. Sankaran, C. Audet and A.L. Marsden. A method for stochastic constrained optimization using derivative-free surrogate pattern search and collocation. *Journal of Computational Physics*. 229(12):4664-4682, 2010.
9. C. Audet, G. Savard and W. Zghal. A mesh adaptive direct search algorithm for multiobjective optimization. *European Journal of Operational Research*. 204(3):545-556, 2010.
10. C. Audet, S. Belhaza, and P. Hansen. On Proper Refinement of Bimatrix Games Extreme Nash Equilibria. *Automatica*. 48 (2) 297-303, 2012.
11. A. Saucier, and C. Audet. Construction of sparse signal representations with adaptive multiscale orthogonal bases. *Signal Processing*. 92(6) 1446-1457, 2012.
12. C. Audet, P. Hansen and S. Perron. Remarks on Solutions to a Non-convex Quadratic Programming Test Problem. *Journal of Global Optimization*, 50(2):363-369, 2011.
13. C. Audet, A. Guillou, P. Hansen, S. Perron and F. Messine. The Small Hexagon and Heptagon with Maximum Sum of Distances Between Vertices. *Journal of Global Optimization*, 49(3):467-480, 2011.
14. C. Audet, X. Fournier, P. Hansen, S. Perron and F. Messine. A Note on Diameters of Point Sets. *Optimization Letters*. 4(4): 485-495, 2010.

Accepted for Publication:

1. S. Alarie, C. Audet, V. Garnier, S. Le Digabel and L.A. Leclaire. Snow water equivalent estimation using blackbox optimization. Technical report, Les Cahiers du GERAD G-2011-09, 2011. To appear in *Pacific Journal of Optimization*.

2. C. Audet, K. C. Dang and D. Orban. Efficient Use of Parallelism in Algorithmic Parameter Optimization Applications. Technical report, Les Cahiers du GERAD G-2011-03, 2011. To appear in Optimization Letters.
3. C. Audet, J.E. Dennis and S. Le Digabel. Trade-off studies in blackbox optimization. Technical report, Les Cahiers du GERAD G-2010-49, 2010. To appear in Optimization Methods and Software.
4. C. Audet, and J. Ninin. Maximal perimeter, diameter and area of equilateral unit-width convex polygons. Technical report, Les Cahiers du GERAD G-2010-37, 2010. To appear in Journal of Global Optimization.

Changes in research objectives: None.

The goal of our project remains: The design, analysis, and implementation of optimization tools to aid in making and documenting decisions involving trading off multiple objectives for mixed variable, generally constrained problems with no global smoothness assumptions.

Change in AFOSR program manager, if any: None

Extensions granted or milestones slipped, if any: None

New discoveries, inventions, or patent: None