Operations research and multi-objective optimization
by

Xavier Gandibleux and Matthias Ehrgott

University of Nantes and CNRS, France

Environment

The LINA (Laboratoire d'Informatique de Nantes Atlantique) is the Computer Science laboratory of the Nantes-Atlantique region of France (FRE CNRS 2729 today, UMR CNRS from January 2008). The lab is hosted by the University of Nantes and the Ecole des Mines de Nantes (School of Engineering) and counts 70 permanent staff. Its scientific project is to develop international research in the "Computer Sciences", with two principal orientations: Distributed software architectures and decision-aid systems. The lab's research teams work on several areas of optimization, such as constraint programming, integer programming, graph theory, bio-informatics, preference modelling and data mining, to name a few.

Formally created in December 2006, the team « Operations research and multi-objective optimization » (ROOM) is the youngest and the smallest of the 11 research teams hosted by the LINA. It is located at the Faculty of Sciences, University of Nantes. With this team, OR and MCDM are now two additional areas of optimization covered by the lab.

The Team

With the recruitment of Xavier Gandibleux in 2004 as full professor in Computer Science by the University of Nantes, and Matthias Ehrgott in 2006 as director of research at the CNRS within LINA, the team is built on basis of more than 10 years of joint work in multi-objective optimization. In 2007, Anthony Przybylski has been recruited by the University of Nantes and he has joined the team as assistant professor. The core of the team consists of these three permanent members.

Non-permanent members are involved in the team for some periods. Sana Belmokhtar (from Ecole des Mines de Saint-Etienne) has joined us as researcher in 2006-2007. She is now assistant professor at the University of Nancy at Epinal. Hadrien Hugot (who is finishing his PhD thesis at LAMSADE, University of Paris Dauphine) got a post-doctoral position in our tem funded by the CNRS. He will join us for one year, starting in October 2007.

Master and PhD students contribute to the works of the team. Currently Julien Jorge is preparing his PhD thesis and another PhD student will joint us soon. Former PhD students who prepared their thesis under our supervision are Xavier Delorme (now assistant professor, Ecole des Mines de Saint Etienne) and Anthony Przybylski (now assistant professor, University of Nantes).

Research Activities

Our work, based on discrete optimisation in Operations Research, focuses on the accumulation of knowledge towards the development of advanced optimization methods that are capable of solving complex optimization problems in reasonable time. The optimization problems of interest are reference problems in discrete optimization and their application in socio-economic contexts, such as railway transportation (capacity of railway infrastructure), airline operations (crew scheduling), communication networks (routing policies, deployment of new infrastructure), and health (radiotherapy treatment of cancer).

In this context, the motivation characterizing the research direction of the team is to study, model, and solve large scale multiobjective discrete optimization problems. Procedures for these problems are essentially problem dependent and employ, among others, efficient enumerative methods or hybrid optimization techniques (multiobjective metaheuristics and exact algorithms). Our research directions are:

1. **Fundamental:** Study, characterization, and understanding of discrete and combinatorial multiobjective optimization problems.

2. **Methodological and algorthmical:** New techniques and methods for the solution of large scale discrete and combinatorial multiobjective optimization problems; Development of algorithms to improve the efficient solution of NP-hard single and multiobjective problems.

3. **Validation and verification:** Application to real world multiobjective optimization problems with the ultimate goal of being able to solve concrete problems in complex real world environments (production systems, transport, communication, health). Most applications are collaborations with industrial partners such as Alcatel, France Telecom, SNCF, DB, Auckland Hospital, Air New Zealand.

Some Results of Our Work

State of the Art Annotated Bibliographic Survey. For many years we collected and summarized the literature on multi-objective combinatorial optimization (MOCO) problems. In 2000 and in 2002, papers reporting our synthesis have been published. Later we did a similar work about multi-objective metaheuristics (MOMH).

M. Ehrgott, X. Gandibleux (2000). A Survey and annotated bibliography of multiobjective combinatorial optimization. OR Spektrum, *22(4): 425-460.*

Path-relinking for multi-objective optimization. Approximation methods for MCDM problems have received a lot of attention in recent years. With two Japanese colleagues we introduced the path-relinking concept for MOMH with success for many MOCO problems.

X. Gandibleux, H. Morita, and N. Katoh (2004). Evolutionary operators based on elite solutions for bi-objective combinatorial optimization. Chapter 23 in *Applications of Multi-Objective Evolutionary Algorithms* (C. Coello Coello and G. Lamont Eds.), pp. 555-579. Advances in Natural Computation Vol. 1, World Scientific, Singapore.

Two phase method for MOCO problems. Introduced in the nineties by Ulungu and Teghem, this method has been considered as a generic method for bi-objective optimization problems. One of the major contributions Anthony Przybylski's PhD thesis has been the generalisation of this method for dealing with problems with more than two objectives.

A. Przybylski (2006) *Méthode en deux phases pour la résolution exacte de problèmes d'optimisation combinatoire comportant plusieurs objectifs : nouveaux développements et application au probléme d'affectation linéaire.* PhD thesis, University of Nantes, December 2006 (In French).

Exact and efficient procedures for solving the linear assigment problem with two and three objectives: Considered as a fundament optimization problem, we proposed algorithms for the exact solution. They have been demonstrated to be the most efficient algorithms considering the literature available.

A. Przybylski, X. Gandibleux and M. Ehrgott (2008). Two-phase algorithms for the bi-objective assignment problem. European Journal of Operational Research *185(2):509-533*

Railway infrastructure capacity The question investigated here can be stated as follows: « How many trains can go through a junction or a station? ». With the cooperation of partners we developed methodologies, algorithms and software dealing with this question. The case studies are real situations from the SNCF (France) and the DB (Germany) networks.

J. Rodriguez, X. Delorme, X. Gandibleux, Gr. Marlière, R. Bartusiak, F. Degoutin, and

S. Sobieraj (2007). RECIFE: models and tools for analyzing rail capacity. *Recherche Transports Sécurité,* 95:19–36.

 Optimization of radiotherapy treatment design: This complex problem concerns the selection of beams, optimization of beam intensity and scheduling of the treatment unit in order to deliver a radiation dose that destroys the tumour while protecting healthy tissue. The team has conducted work on all aspects of this problem.

L. Shao, M. Ehrgott (2007). Approximately solving multiobjective linear programmes in objective space and an application in radiotherapy treatment planning. *Mathematical Methods of Operations Research.* Accepted for publication.

Some Major Events Involving the Team Members

The members of the team have been involved in several international scientific events, four of which are immediately related to the MCDM field.

1. MOMH 2002: Multiple Objective Metaheuristics Workshop, November 4-5, 2002, Paris - France
http://webhost.ua.ac.be/eume/welcome.htm?workshops/momh/fillinaddress.php&1

2. MOPGP 2006: 7th International Conference on Multi-Objective Programming and Goal Programming, June 12–14, 2006, Loire Valley (Tours), France http://www.mopgp06.org/

3. MCDM 2008 : 19th International Conference on Multiple Criteria Decision Making, 7 - 12 January 2008, Auckland, New Zealand https://secure.orsnz.org.nz/mcdm2008/

4. EMO 2009: 5th International Conference on Evolutionary Multi-Criterion Optimization. First Semester 2009, Nantes, France http://www.emo09.org/

 At the national level, the French Working Group dedicated to Multiple-Objective Programming (PM2O) has been co-founded on 1999 by Xavier Gandibleux. He has served as the coordinator of this group for four years.

Visitors and Collaborators

Invited professors who visited us recently for a period of one month were Kathrin Klamroth in 2005 (University of Erlangen-Nuremberg, Germany), Eric Taillard in 2006 (HEIG-VD, Switzerland), and Margaret Wiecek in 2007 (Clemson University, USA).

The team also hosts visiting PhD students: Daniel Salazar Aponte from University Las Palmas de Gran Canaria (6 months from Sept 2005) and Andrea Raith from Auckland University (3 months from August 2007). If you are interested in visiting us, please contact us.

We have a long tradition of working with colleagues in OR and MCDM. Several collaborations are on-going with Karl Doerner and Sophie Parragh (University of Vienna, Austria), Dario Da Silva (University of Nottingham, UK), Naoki Katoh (Kyoto University) and Hiroyuki Morita (Osaka Prefecture University) to name a few.

Since 1999 we are involved in research works related to railway transportation. Joaquin Rodriguez (from INRETS, the French National Research Institute on Transportation and Security) is one of our collaborators on this topic.

To conclude this section, we are collaborating also with colleagues of regional institutions: Fabien Le Huédé (Ecole des Mines de Nantes), Philippe Dépincé (Ecole Centrale de Nantes), Vincent Barichard (University of Angers) and Marc Sevaux (University of South Brittany-Lorient).

Projects

The team is strongly involved in a large regional project called MILES since the regional council « Pays de la Loire » has recognized « Decision Aid Systems » as a prioritized research theme. In associating the regional research teams in optimization inside this project, it represents a significant task force in the west of France.

Software

RECIFE is a decision support system specifically designed for the analysis of railway infrastructure capacity. For a given station or node of the network, various functionalities such as verifying the feasibility of expected traffic, studying infrastructure saturation and stability of resulting timetables are offered to a decision maker. Two geographical situations have already been studied: The Pierrefitte-Gonesse node located north of Paris and the Lille-Flandres station.

Some References

1. V. Barichard, M. Ehrgott, X. Gandibleux and V. T'kindt (editors). Multi-Objective Programming and Goal Programming. Berlin, Springer, Forthcoming.

2. M. Ehrgott, J. Figueira, X. Gandibleux (editors). Multiobjective Discrete and Combinatorial Optimization. Annals of Operations Research 147. 2006.

3. J. Figueira, S. Greco, M. Ehrgott (editors). Multiple Criteria Decision Analysis. State of the Art Surveys. International Series in Operations Research and Management Science 78. Berlin, Springer, 2005.

4. M. Ehrgott. Multicriteria Optimization. Second edition. Berlin, Springer, 2005.

5. X. Gandibleux, M. Sevaux, K. Sörensen and V. T'kindt (editors). Meta-heuristics for Multiobjective Optimisation. Lecture Notes in Economics and Mathematical Systems 535. Berlin, Springer, 2004.

6. M. Ehrgott and M. Luptacik (editors). 16th International Conference on Multiple Criteria Decision Making. Journal of Multi-Criteria Decision Analysis 12(1) 2003.

7. M. Ehrgott and X. Gandibleux (editors). Multiple Criteria Optimization: State of the Art Annotated Bibliographic Survey. International Series in Operations Research and Management Science 52. Boston, Kluwer 2002.

8. X. Gandibleux, A. Jaszkiewicz, A. Fréville, and R. Slowinski (guest editors). Special issue ``Multiple Objective MetaHeuristics''. Journal of Heuristics 6(3) 2000.

To Contact Us:

XAVIER GANDIBLEUX

LINA - Laboratoire d'Informatique de Nantes Atlantique (FRE CNRS 2729)

Université de Nantes

2, rue de la Houssinière BP 92208

F-44322 Nantes Cedex 03 - FRANCE

http://lina.atlanstic.net/en/equipes/team11/