Surveys in operations research

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Abstract
We introduce the series of *Annals of Operations Research* issues that collects updated versions of the invited surveys that appeared in the journal *4OR: A Quarterly Journal of Operations Research*.

Keywords Survey · Collection · *4OR: A Quarterly Journal of Operations Research*

1 Foreword

There exists a long standing collaboration between *4OR: A Quarterly Journal of Operations Research* and the *Annals of Operations Research (AOR)*: on a triennial basis, the editors-in-chief of *4OR* are invited by *AOR*'s editor-in-chief to serve as guest editors of a special issue of *AOR* that collects surveys that have appeared in the last three volumes (consisting of four issues each) of *4OR*. In line with this tradition, the present issue collects seven surveys from volumes 13–15 (2015–2017) of *4OR* (see the Preface). This issue follows those of Bouyssou et al. (2007a, 2010a) and Liberti et al. (2013b, 2016b).

The success of this on-going collaboration essentially rests on the excellence of the surveys themselves: we take great pride in the survey section of *4OR*, and place considerable effort into inviting prestigious authors, covering a large range of topics in great depth, and exploring new "hot" topics in Operations Research (OR). Their re-publication makes our surveys more widely available to the OR community and offers the authors the opportunity to revise, update and sometimes substantially improve their past work. (The fact that *4OR* and *AOR* are both

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2 About *4OR*

In 2002, the Belgian and Italian Operations Research societies (respectively, ORBEL and AIRO) decided to stop publishing their historical national journals, *JORBEL* and *Ricerca Operativa*. The goal (see Bouyssou et al. 2003) was to optimize the use of scarce resources and to jointly launch a new journal with better international visibility. The Belgian and Italian societies were soon joined by the French Operations Research society (ROADEF) and, with the help of Springer, they started publishing *4OR* in 2002. As its name suggests, this journal is "for" Operations Research (OR). The full name of the journal was originally *Quarterly Journal of the Belgian, French and Italian Operations Research Societies*, but soon (in 2004) changed to *4OR: A Quarterly Journal of Operations Research* so as to better reflect its growing international impact.

4OR is managed by a group of three editors-in-chief, one from each promoting national OR society, assisted by a board of highly qualified area editors. (For the period 2015–2017, the editors-in-chief were the authors of this editorial, up to the fact that Michel Grabisch replaced Leo Liberti from 2016 on). Every third year, the editors-in-chief prepare a report on the latest three years of existence of the journal (see Bouyssou et al. 2006a, 2009a; Liberti et al. 2012, 2015; Crama et al. 2018).

Every year, one volume of four issues, each around 110 pages, is published. Papers fall into five different sections, as follows (we indicate in parentheses the total number of papers in each category for volumes 13, 14, and 15):

Invited surveys (9): State-of-the-art surveys written by prominent researchers on invitation by the editors, with at most one survey per issue.

Research papers (40): Original research papers, whose average and median length is about 20 pages. The journal publishes papers in *all* areas of OR. Papers in emerging fields of OR are especially welcome.

PhD thesis abstracts (25): Two-page summaries of PhD theses defended in Belgian, French, or Italian institutions, or by Belgian, French, or Italian students graduating abroad. The summaries are published under the responsibility of the PhD advisors.

Industry (3): Case studies, state-of-the-art papers on the applications of OR techniques, or reflections on the practice of OR.

Educational papers (0): Up-to-date expositions of classical problems and methods that are frequently encountered in OR classes, or papers throwing a novel light on such.

All submitted papers are handled and processed in electronic form. The refereeing process conforms with the usual standards of academic journals and aims to maintain the highest quality. After having passed a check for plagiarism (using ©iThenticate) and a quick scan for appropriateness and level, the process involves at least two independent referee reports and the advice of an appropriate area editor. Except for several cases of plagiarism (including a case of usurped identity) that were fortunately detected (see Bouyssou et al. 2006b, 2009b; Crama et al. 2016), the reviewing process of the papers is usually rather smooth. The collaboration between the three editors and the area editors proves effective and efficient. Our purely electronic process for handling submissions turns out to be swift and economical.

For volumes 13–15, the rejection rate for research papers was 93%. The mean time between the reception of the paper and the communication of the decision to the authors was 65 days, i.e., approximately 2 months. We received submissions coming from 61 different countries.

3 The first four issues

The fifty-two surveys published in the first 15 years of existence of *4OR* offer an in-depth coverage of diverse "hot fields" in Operations Research. We briefly present here, in chronological order, the surveys that were included in the first four *Annals of Operations Research* volumes (Bouyssou et al. 2007a, 2010a; Liberti et al. 2013b, 2016b), referring the reader to Bouyssou et al. (2007b, 2010b) and Liberti et al. (2013a, 2016a) for a more detailed description.

The omnipresence of Lagrange (*4OR* 1/1, Lemaréchal 2003): Claude Lemaréchal points out that Lagrangean relaxation is not just a technique for handling combinatorial optimization problems, but a basic method in many more optimization issues.

The dial-a-ride problem: models and algorithms (*4OR* 1/2, Cordeau and Laporte 2003): Jean-François Cordeau and Gilbert Laporte present an exhaustive introduction to door-to-door delivery problems arising in social services.

Lifting, superadditivity, mixed integer rounding and single node flow sets revisited (*4OR* 1/3, Louveaux and Wolsey 2003): Quentin Louveaux and Laurence Wolsey show that a combination of integer rounding and lifting techniques provides a unified way to obtain many of the valid inequalities for mixed 0–1 sets that have been proposed in the literature.

Models and solution techniques for frequency assignment problems (*4OR* 1/4, Aardal et al. 2003): Karen Aardal, Stan van Hoesel, Arie Koster, Carlo Mannino, and Antonio Sassano give a thorough overview of the different modeling ideas developed for the various situations in which a frequency assignment problem arises in wireless communication.

Combinatorial auctions (*4OR* 2/1, Abrache et al. 2004): Jawad Abrache, Teodor Gabriel Crainic, Michel Gendreau, and Monia Rekik review several contributions from the Operations Research literature on a particular type of auctions in which participants are allowed to bid on bundles of multiple heterogeneous items.

Ethics in OR/MS: past, present and future (*4OR* 2/2, Brans and Gallo 2004): Jean-Pierre Brans and Giorgio Gallo discuss fundamental questions on the social role of Operations Research/Management Science tools and the new challenges posed by the growing complexity of the problems humanity is facing today.

Combinatorial optimization and hierarchical classifications (*4OR* 2/3, Barthélemy et al. 2004): Jean-Pierre Barthélemy, François Brucker, and Christophe Osswald review several extensions of traditional hierarchical classification techniques from a combinatorial optimization point of view, and study the complexity of the underlying optimization problems.

Counting and enumeration complexity with application to multicriteria scheduling (*4OR* 3/1, T'kindt et al. 2005): Vincent T'kindt, Karima Bouibede-Hocine, and Carl Esswein study several aspects of multicriteria scheduling, with special emphasis on the complexity of problems linked with counting and enumerating optimal solutions.

An overview of bilevel optimization (*4OR* 3/2, Colson et al. 2005): Benoît Colson, Patrice Marcotte, and Gilles Savard review the good progress that is being made in handling special classes of problems in which the objective involves the optimal solution to another second level problem, or admit even more levels.

Complexity and algorithms for nonlinear optimization problems (*4OR* 3/3, Hochbaum 2005): Dorit Hochbaum analyzes the effort needed to produce optimal solutions with pre-specified accuracy for nonlinear continuous optimization problems, and presents polynomial-time methods for several nonlinear network problems.

Production planning with load dependent lead times: an update of research (*4OR* 3/4, Pahl et al. 2005): Julia Pahl, Stefan Voß, and David L. Woodruff give a detailed account of techniques for supply chain management in contexts where it is required to produce goods in a timely manner so as to be able to meet a demand varying in time and space.

Some operations research methods for analyzing protein sequences and structures (*4OR* 4/2, Błażewicz et al. 2006): Piotr Łukasiak, Jacek Błażewicz, and Maciej Miłostan review Operations Research techniques that were relatively recently introduced in biology, especially in the protein analysis area, to support biologists.

Integrating operations research in constraint programming (*4OR* 4/3, Milano and Wallace 2006): Michela Milano and Mark Wallace describe how constraint programming, viewed as a natural formalism for modeling problems, allows linear programming to be combined with propagation and novel and varied search techniques.

Ejection chain and filter-and-fan methods in combinatorial optimization (*4OR* 4/4, Glover and Rego 2006): César Rego and Fred Glover present the general framework of the ejection chain and filter-and-fan methods, powerful neighborhood structures fundamental to the performance of local search and metaheuristic algorithms for combinatorial optimization.

An updated survey on the linear ordering problem for weighted or unweighted tournaments (*4OR* 5/1, Charon and Hudry 2007): Irène Charon and Olivier Hudry survey results, conjectures, and open problems dealing with the combinatorial and algorithmic aspects of the linear ordering problem.

Combinatorial optimization and green logistics (*4OR* 5/2, Sbihi and Eglese 2007): Abdelkader Sbihi and Richard W. Eglese introduce the area of green logistics and describe the main topics in this field which can be formulated as combinatorial optimization problems.

Generalized Nash equilibrium problems (*4OR* 5/3, Facchinei and Kanzow 2007): Francisco Facchinei and Christian Kanzow discuss the main properties and solution algorithms for the generalized Nash equilibrium problem, an important model that has its roots in the economic sciences but is being fruitfully used in many different fields.

Exact algorithms for routing problems under vehicle capacity constraints (*4OR* 5/4, Baldacci et al. 2007): Roberto Baldacci, Paolo Toth, and Daniele Vigo review the most recent developments that had a major impact in the current state-of-the-art of exact algorithms for the capacitated vehicle routing problem.

A decade of application of the Choquet and Sugeno integrals in multi-criteria decision aid (*4OR* 6/1, Grabisch and Labreuche 2008): Michel Grabisch and Christophe Labreuche examine the main advances on the use of the Choquet and Sugeno integrals in multi-criteria decision aid over the last decade.

On the use of graphs in discrete tomography (*4OR* 6/2, de Werra et al. 2008): Dominique de Werra, Marie-Christine Costa, Christophe Picouleau, and Bernard Ries present a tutorial paper on a graph theoretical model for the basic image reconstruction problem which stems from discrete tomography.

Mathematical optimization in intensity modulated radiation therapy (*4OR* 6/3, Ehrgott et al. 2008): Matthias Ehrgott, Çiğdem Güler, Horst W. Hamacher, and Lizhen Shao survey optimization models, methods, and theories in mathematical optimization which were recently successfully introduced in the design of intensity modulated radiotherapy treatments.

Variable neighborhood search: methods and applications (*4OR* 6/4, Hansen et al. 2008): Pierre Hansen, Nenad Mladenović, and José Moreno Pérez review the main aspects of vari-

able neighborhood search metaheuristics, a framework based upon systematic changes of neighborhoods.

Constraint programming-based column generation (*4OR* 7/2, Gualandi and Malucelli 2009): Stefano Gualandi and Federico Malucelli survey recent applications and advances of the constraint programming-based column generation framework, where the master sub-problem is solved by traditional OR techniques, while the pricing subproblem is solved by constraint programming.

The core of games on ordered structures and graphs (*4OR* 7/3, Grabisch 2009): Michel Grabisch gives a unified view of the results that have been obtained by defining a game on a subcollection of the power set of the set of players, examining the implications on the mathematical structure of the core.

Intra-domain traffic engineering with shortest path routing protocols (*4OR* 7/4, Altın et al. 2009): Aysegül Altın, Bernard Fortz, Mikkel Thorup and Ümit Hakan review optimization techniques that have been developed for managing intra-domain routing in networks operated with shortest path routing protocols, and the state-of-the-art research that has been carried out in this direction.

Extended formulations in combinatorial optimization (*4OR* 8/1, Conforti et al. 2010): Michele Conforti, Gérard Cornuéjols and Giacomo Zambelli survey the size of perfect formulations for combinatorial optimization problems, with special emphasis on situations where the addition of a polynomial number of extra variables allows a formulation with a polynomial number of inequalities.

Robust portfolio asset allocation and risk measures (*4OR* 8/2, Scutellà and Recchia 2010): Maria Grazia Scutellà and Raffaella Recchia discuss the mathematical models, and related algorithmic approaches, that have recently been proposed to address uncertainty in portfolio asset allocation, focusing on robust optimization methodology.

Recent progress of local search in handling the time window constraints of the vehicle routing problem (*4OR* 8/3, Hashimoto et al. 2010): Hideki Hashimoto, Mutsunori Yagiura, Shinji Imahori and Toshihide Ibaraki review recent results on how to handle hard and soft time window constraints of the vehicle routing problem, putting emphasis on its different definitions and algorithms.

Makespan minimization in online scheduling with machine eligibility (*4OR* 8/4, Lee et al. 2010): Kangbok Lee, Joseph Y.-T. Leung and Michael L. Pinedo examine online scheduling problems in parallel machine environments with various types of machine eligibility constraints, and the makespan as objective function.

Probabilistic decision graphs for optimization under uncertainty (*4OR* 9/1, Jensen and Nielsen 2011): Finn Jensen and Thomas Nielsen survey probabilistic decision graphs for modeling and solving decision problems under uncertainty, providing an introduction to influence diagrams and to alternative representation languages.

Airport runway scheduling (*4OR* 9/2, Bennell et al. 2011): Julia Bennell, Mohammad Mesgarpour and Chris Potts review the main solution techniques (dynamic programming, branch and bound, heuristics and meta-heuristics) that are used for scheduling aircraft landings and take-offs.

Political districting: from classical models to recent approaches (*4OR* 9/3, Ricca et al. 2011): Federica Ricca, Andrea Scozzari and Bruno Simeone introduce and discuss selected optimization models and algorithms for political districting, which gave rise to the main lines of research on this topic in the Operations Research literature of the last five decades.

Mixed integer nonlinear programming tools: a practical overview (*4OR* 9/4, D'Ambrosio and Lodi 2011): Claudia D'Ambrosio and Andrea Lodi review available tools for solving

mixed integer nonlinear programming problems, with the aim of giving the reader a flavor of the difficulties one can face in this field.

Learning from conflicts in propositional satisfiability (*4OR* 10/1, Hamadi et al. 2012): Youssef Hamadi, Saïd Jabbour and Lakhdar Saïs discuss the application of machine learning techniques to SAT solving.

The symmetric quadratic knapsack problem: approximation and scheduling applications (*4OR* 10/2, Kellerer and Strusevich 2012): Hans Kellerer and Vitaly Strusevich discuss fully polynomial time approximation schemes for the Symmetric Quadratic Knapsack Problem and the Half-Product Problem, and their application to various scheduling problems.

Relaxations of mixed integer sets from lattice-free polyhedra (*4OR* 10/3, Del Pia and Weismantel 2012): Alberto Del Pia and Robert Weismantel give an introduction to a recently established link between the geometry of numbers and mixed integer optimization.

Semidefinite relaxations for partitioning, assignment and ordering problems (*4OR* 10/4, Rendl 2012): Franz Rendl introduces the field of semidefinite optimization for non-experts. The basic concepts are explained on a mostly intuitive level. A variety of semidefinite optimization models are presented on a selection of graph optimization problems.

Bilevel programming and price setting problems (*4OR* 11/1, Labbé and Violin 2013): Martine Labbé and Alessia Violin present the main concepts, models and solution methods of pricing optimization problems which can be modeled as bilevel programs.

Combining metaheuristics with mathematical programming, constraint programming and machine learning (*4OR* 11/2, Talbi 2013): El-Ghazali Talbi gives a rational, categorized view of the field of hybrid metaheuristics, discussing in particular the case of hybridization with mathematical programming and constraint programming.

Using multi-objective evolutionary algorithms for single-objective optimization (*4OR* 11/3, Segura et al. 2013): Carlos Segura, Carlos Coello Coello, Gara Miranda and Coromoto León present the main methods that allow the use of multi-objective schemes for single-objective optimization, and discuss several open topics and some possible paths of future work in this area.

Global optimization based on local searches (*4OR* 11/4, Locatelli and Schoen 2013): Marco Locatelli and Fabio Schoen deal with the use of local searches within global optimization algorithms, and present how the associated issues have been faced in the existing literature.

Merit functions: a bridge between optimization and equilibria (*4OR* 12/1, Pappalardo et al. 2014): Massimo Pappalardo, Giandomenico Mastroeni and Mauro Passacantando review the literature about merit functions for variational inequalities, quasi-variational inequalities and abstract equilibrium problems.

On scheduling with the non-idling constraint (*4OR* 12/2, Chrétienne 2014): Philippe Chrétienne gives an overview of the main results obtained on the complexity of scheduling under the non-idling constraint, i.e, when the jobs assigned to each machine must be processed with no intermediate delay.

Deriving compact extended formulations via LP-based separation techniques (*4OR* 12/3, Lancia and Serafini 2014): Giuseppe Lancia and Paolo Serafini introduce a unified view of compact extended formulations applied to combinatorial optimization problems.

Simulation optimization: a review of algorithms and applications (*4OR* 12/4, Amaran et al. 2014): Simulation optimization refers to the optimization of an objective function subject to constraints, both of which can be evaluated through a stochastic simulation. Satyajith Amaran, Nick Sahinidis, Bikram Sharda and Scott Bury review some of the diverse applications that have been tackled by these methods and speculate on future directions in the field.

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