

Jakub Mareček: An Overview of Publications

My work falls into three broad categories:

1. “Mathematical Programming”: Novel approaches to well-known optimisation problems, tested on widely-available benchmark instances
2. “Applied Operations Research”: The development of solvers for real-life problems or their mild abstractions
3. “Computer Science”: Algorithm design for simple scheduling and optimisation problems, with detailed analyses

Across the three categories, I am interested in particular in:

- Exact methods in combinatorial optimisation based on binary linear programming
- Fast exact methods for convex programming, or seen another way, heuristic methods for convex integer programming.

- (1) ♦ **Space-Indexed Formulations of Packing Boxes into a Larger Box**, joint work with Edmund K. Burke and Sam Allen, *Operations Research Letters* (2012) 40(1): 20–24
No integer linear programming solver could prove 11 unit-cubes cannot be packed into a container of dimensions $1 \times 1 \times 10$ within an hour using the previous best formulation of Chen/Fasano/Padberg. We present a novel formulation of 3D packing problems. We can prove optimality of instances with ten million unit-cubes. On realistic van-loading instances, we can pack hundreds of boxes optimally.
- ♦ **A Supernodal Formulation of Vertex Colouring with Applications in Course Timetabling**, joint work with Edmund K. Burke, Hana Rudová, and Andrew J. Parkes, *Annals of Operations Research* (2010) 179(1): 105–130
We present a novel compact formulation of graph colouring or, seen another way, the best possible transformation of graph colouring to multi-colouring. Our formulation typically reduces the run-times of integer linear programming solvers by the factor of three to five, compared with the usual compact formulation.
- (1) (2) ♦ **Semidefinite Programming Relaxations in Timetabling**, joint work with Edmund K. Burke and Andrew J. Parkes, *Practice and Theory of Timetabling 2010*, extended version on-line
We present novel SDP relaxations of bounded graph colouring and related problems in timetabling and a particularly efficient matrix-free implementations of augmented lagrangian methods for solving them.
- ♦ **A Primal Heuristic for Integer Linear Programming with Automated Aggregations**, joint work with Edmund K. Burke and Andrew J. Parkes, *International Symposium on Mathematical Programming 2009*, with an extended version only in my dissertation, so far
We present a framework for aggregating variables in integer linear programs, so as to allow for generation of primal or dual bounds or both.

- (2)
- ◇ **Decomposition, Reformulation, and Diving in University Course Timetabling**, joint work with Edmund K. Burke, Hana Rudová, and Andrew J. Parkes, *Computers and Operations Research* (2010) 37(3): 582–597, with pre-print on-line
We present a broad framework for the development of integer programming decompositions in timetabling and a solver for Udine Course Timetabling, which is very competitive with the present-best column-generation heuristics by Prof. Lübbecke and his students.
 - ◇ **A Branch-and-Cut Procedure for the Udine Course Timetabling Problem**, joint work with Edmund K. Burke, Hana Rudová, and Andrew J. Parkes, *Practice and Theory of Automated Timetabling 2008*, with an extended version on-line and in *Annals of Operations Research* (2012) 194(1), 71–87
We present a branch-and-cut procedure for the Udine Course Timetabling problem. In comparison with compact binary linear programming formulations, we use fewer variables and an exponential number of constraints. The constraints of several types are added only upon violation.
 - ◇ **Take-off Sequencing at the Stands of London Heathrow: A Model and Solution Method**, joint work with Jason A. D. Atkin, Edmund K. Burke, and John S. Greenwood at National Air Traffic Services, submitted
We present integer quadratic programming models and piece-wise linear approximations of a scheduling problem.
 - ◇ **Programming Language for Optimisation with Semi-Automated Reformulations**, joint work with Edmund K. Burke and Andrew J. Parkes
It is often not clear what compact formulation of a particular problem is the best and presently available tools do not make it easy to experiment. We present a free parser for OPL with additional key-words enabling generation of a number of variants of a formulation from a succinct description and tools automating the running of the experiments. Still not quite finished.
 - ◇ **A Cutting Surface Method for Integer Least Squares with Application in MIMO Signal Decoding**, joint work with the staff of ARM Ltd.
Modern wireless networks, such as IEEE 802.11n (WiFi N), LTE and LTE Advanced, use multiple transmit antennas and multiple receive antennas. Decoding the signal in this setting involves solving an NP-Hard problem at megahertz rates. We implement a variant of Atamturk’s second-order cone rounding cuts together with a C-based interior point method.
 - ◇ **A Semidefinite Programming Relaxation of Integer Least Squares with Applications in MIMO Signal Decoding**, joint work Florian Jarre
The problem of finding a box-constrained integer solution minimising a least squares objective (ILS) has numerous applications, notably in decoding digital signal in multi-antenna systems. The problem can be reformulated as an instance of the maximum cut (MAXCUT) problem in a graph, where the number of vertices is polylogarithmic in the arity of variables in ILS. Based on the reformulation and the rich history of work on semidefinite programming relaxations of MAXCUT, one can solve a relaxation much faster than previously proposed relaxations.
- (3)
- ◇ **Dynamic Data Structures for Taskgraph Scheduling Policies with Applications in OpenCL Accelerators**, joint work with the staff of ARM Ltd., *Multidisciplinary International Scheduling Conference 2011*, with an extended version on-line, invited and submitted to the *Journal of Scheduling*
We present and analyse dynamic data structure for implementing scheduling policies for precedence-constrained jobs.
 - ◇ **Some Probabilistic Results on Width Measures of Graphs**, *Graph Classes, Optimization, and Width Parameters 2009*, with an extended abstract on-line
I show there are asymptotically almost surely lower bounds on the treewidth, branchwidth, cliquewidth, NLC-width, and rankwidth of graphs drawn from a simple random model.

- ◇ **A Polylog Algorithm for Linear Discrete Optimization in 3D**, my undergraduate thesis with Petr Hliněný is on-line
We present and analyse poly-logarithmic algorithms for a problem related to integer linear programming in dimension three.
- (3) (1) ◇ **A Distributed Coordinate Descent Method for Composite Function Minimisation with Applications in Training Sparse Support Vector Machines**, joint work with Peter Richtárik and Martin Takáč, in progress
A distributed coordinate descent for the sums of a convex smooth and a convex non-smooth function of certain properties is analysed and tested empirically. A number of algorithms for distribution and synchronisation of the computation across a cluster of multi-core computers are proposed. Tight bounds on the rates of the convergence of the method are shown, assuming non-trivial, non-random distribution of the workload. An OpenMP/MPI implementation of training Sparse Support Vector Machines is tested on a data set of 14.000 human genomes from the Wellcome Trust.
- ◇ **Exploiting Structure in Integer Programs**, my PhD dissertation, available on-line
The case for exploiting certain structures in integer linear programs is argued. Many alternative approaches to integer linear programming can be cast in the following, novel framework. “Structure” in any integer linear program is a class of an equivalence among triples of algorithms: deriving combinatorial objects from the input, adapting them, and transforming the adapted object to solutions of the original integer linear program. Such alternative approaches are, however, inherently incompatible with branch and bound solvers. A structure is defined to be “useful”, only when it extracts submatrices, which allow for the implementation of more than one of the four types of heuristics required in the branch and bound approach. Three examples of such useful structures are presented: aggregations of variables, mutual-exclusion components, and precedence-constrained components. On instances from complex timetabling problems, where such structures are prevalent, a general-purpose solver, based on this approach, closes the gap between primal and dual bounds to under five percent, orders of magnitude faster than using state-of-the-art general-purpose solvers.