Scientific Report*
New MIP techniques for branch-and-cut approaches for large-scale problems, part III

Markus Sinnl†

Host: Matteo Fischetti
DEI-University of Padua

1 Purpose of the STSM

The aim of the STSM was to continue the work with the group of Matteo Fischetti, which started with STSMs in April and July last year. In this joint work, we focus on branch-and-cut approaches for very large-scale instances of "classic" combinatorial optimization problems. The problems we currently work on are the Steiner tree problem (STP) and variants of it and the uncapacitated facility location problem (UFL). Both the STP and the UFL are very basic, well-established problems, which have many variants, which appear as problems, or subproblems in energy production and distribution. For example, the prize-collecting Steiner tree can be used to model district heating networks [9] and the node-weight connected subgraph problem (which is a variant of the Steiner tree problem) can be used to model optimization problems related to oil-drilling [8]. Facility location models are, e.g., used to locate power plants [1], [2], wind-farms turbines [3], [4] or to find optimal locations for oil-drilling sites [7].

2 Description of the work carried out during the STSM

The first two days where devoted to finishing our paper on the STP for the *Mathematical Programming Computation* special issue associated with the 11th DIMACS implementation challenge. Our approach won in most of the categories it competed in the challenge[1].

In the remaining days we finalized our work on UFL, whose main outcomes are described below. It quickly became obvious that the classical ILP-model for the UFL, which has $O(|I||J|)$ variables, where $|I|$ is the number of facilities and $|J|$ is the number of customer, will become prohibitive for solving large-scale instances. We thus went for a "thinning out" approach of removing unnecessary variables and constraints, which had turned out to be very successful in our work for the STP. In this quest, we ended up with a model based on Benders decomposition, which was previously proposed by [10], but was apparently never computationally investigated in recent years. We developed an extension of this model (based on generalized Benders decomposition), which also allows it to tackle the UFL with separable quadratic convex costs (qUFL).

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†markus.sinnl@univie.ac.at. ISOR, Department of Business, Economics and Statistics, University of Vienna, Austria

[1] http://dimacs11.cs.princeton.edu/contest/results/results.html

The qUFL has recently been introduced in [6] and the state-of-the-art approach is based on a perspective reformulation [5].

For the UFL, we are able to prove optimality for seven previously unsolved instances from the UFLLIB[2] and provide improved best solutions for many other unsolved instances. For the qUFL, the results are even better, our approach is up to four magnitudes faster than the current state-of-the-art approach [5], and is able to tackle large-scale instances, for which the state-of-the-art approach runs into memory-trouble.

3 Future collaboration with the host institution

We are already working on applying the generalized Benders decomposition approach to other convex problems.

4 Foreseen publications

The paper on STP will be submitted to the special issue of *Mathematical Programming Computation* associated with the DIMACS challenge. The paper on UFL will be submitted to a top journal.

5 Confirmation by the host institution of the successful execution of the STSM

Sent by Matteo Fischetti.

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