Scientific report of Alberto Ceselli

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Field of Research:	Computational Integer Programming
Topic:	Algorithms for routing and scheduling problems
PhD Fellow	at the program from July 2005 to Dec. 2005

Field of Research

Integer linear programming has shown to be a practical tool for modelling and solving a wide range of problems in logistics. In particular, column generation is an increasingly popular technique for tackling large-scale integer programs. Embedding column generation in branch-and-bound algorithms yields the so called branch-and-price paradigm.

The main aim of our research has been to apply these techniques to two real-world problems arising in the context of railroad optimization.

First, we considered the optimization of a steel production site. Here, rail cars containing different kind of steel are placed on tracks of a private network. They have to be arranged in trains (shunting problem), that are subsequently coupled by engines and delivered at destination sites (routing problem).

Second, we considered the optimization of a rail freight delivery system of the Swiss Railways. In this case, the customers formulate a request of shipping a certain amount of goods, organized in rail cars, from a station to another of the network. During the night, freight trains pickup the customer goods and deliver them to some central hubs, where they are re-organized. Then, new trains depart from the hubs for the deliveries.

Results

Steel production site. This has been a joint work with M. Lübbecke and I. Spenke. For the shunting problem, we developed two polynomial-size mixed integer programming formulations, modelling respectively the case in which a train for a single shipment has to be organized, or trains for several shipments have to be arranged at once. We also devised a heuristic for the single shipment case. The routing problem resembles a vehicle routing with pickup and delivery, with the additional feature of allowing the 'sharing' of tracks

between the vehicles, provided they are not on the same track at the same time. For this problem we designed a branch-and-cut-and-price approach. The pricing problem is a resource-constrained shortest path problem with several additional features, for which we devised a dynamic programming algorithm. The master problem is a set covering problem with an additional constraint for each track of the network and for each instant in time. We dynamically generate this second set of constraints. We also considered the main algorithmic issues of the method, like special purpose branching rules and columns management techniques. The implementation of these methods is still under way.

Swiss Railways. This has been a joint work with M. Lübbecke and H. Schilling (TU Berlin), M. Gatto and M. Nunkesser (ETH Zürich). We tackled this problem with a branch-and-price methodology too. In this case, the master involves three kind of variables, modelling pickup paths, shifting of rail cars to one hub to another and delivery paths respectively; moreover it consists of a set of covering constraints and several side constraints, modelling capacity restrictions at each hub, flow of shipments and engines at different moments in time. The pickup and delivery paths are generated by resource constrained shortest path algorithms, while hub-to-hub paths are generated by knapsack algorithms. We considered several additional issues like avoiding symmetries in the search tree, devising effective rounding heuristic and contracting the original network to speed-up the computation.

For both problems we were able to deal with real data, given by the industrial partners.

During my stay at the Marie Curie Training Site in Berlin, I had the opportunity of widening my research horizons by attending the activities of the CGC and collaborating with other researchers. I also had many insight discussions on the topics of my thesis with the members of the COGA group, which definitely sharpened my view of the field.

Activities

- Completion of my PhD thesis [1].
- Attendance to the Monday meetings of the CGC program.
- Attendance to the Thursday seminars of the COGA group at the TU.
- Participation to the CGC annual workshop in Hiddensee.
- Attendance to the block course "CO@Work" at the ZIB.

Contributions:

- "An optimization algorithm for the ordered open-end bin-packing problem", CGC annual workshop at Hiddensee (September 25-28, 2005).
- "Branch and price algorithms for partitioning problems", Thursday seminars of the COGA group (September 29, 2005).
- "Penalized and ordered knapsack problems", CGC colloquium (December 05, 2005).

Preview

- I will defend my PhD thesis during the first months of 2006 [1].
- A preview of the steel-production problem has been reported in [2]; the implementation of our algorithms is still under way; we are planning to presented some of our results in [4].
- A report regarding the Swiss Railways problem will be presented at [3]. A prototype implementation is already running, but further work has to be carried out, together with detailed computational evaluation.

References

[1] Ceselli A., Branch and price algorithms for partitioning problems, PhD Thesis in Computer Science, to be defended at the Università degli Studi di Milano, 2005

[2] Ceselli A., Lübbe J., Lübbecke M., Spenke I., poster: Locomotives and Rail Cars: Switching, Routing, and Scheduling, IMA "Hot Topics" Workshop: Mixed-Integer Programming, Minneapolis, July 25-29, 2005

[3] Ceselli A., Gatto M., Lübbecke M., Nunkesser M., Schilling H., Cargo trains at night at Swiss Railways, 10th Combinatorial Optimization Workshop, Aussois, January 8-13, 2006

[4] Ceselli A., Lübbecke M., Spenke I., Industrial Railroad Operations: Optimal Switching, Routing, and Scheduling, High Performance Scientific Computing, Hanoi, Vietnam, March 6-10, 2006