P O Lindberg, polin@kth.se

TEK/VTI 2015-01-06

Two Master’s Thesis Projects Concerning Railroad Timetabling.

*Overview*

As part of a pilot study for Trafikverket (Swedish Transport Administration) concerning the feasibility of automated railroad timetabling, we announce two Master’s Thesis projects, in Computer Science/ Optimization, described below.

The construction of a railroad timetable, the Railroad Timetabling Problem (RTP), is a complex task. Several different train types have to share the scarce track capacity. On each block (track section) there must be at the most one train at a time. Trains must also have a separation in time, known as headway. In addition, faster trains (such as X2000) must be able to overtake slower trains (such as freight and regional trains). These aspects must be addressed in order to strike a balance between the needs of various train requests.

At present, the time-tabling is done essentially manually, but with the support of running time simulators, to compute running times of different alternatives. Each new timetable in essence is a modification the existing timetable, which obviously is operable.

However, there are great opportunities to automate the RTP.

Already in 1998 the undersigned (and colleagues) published an article (Brännlund et al, 1998) demonstrating how automation could be handled. There, the RTP was stated as an optimization problem which was solved through lagrangian relaxation and column generation. We solved the RTP for a single track railway in Sweden.

An overview of our approach for RTP looks as follows (all need not be understood):

We think of time as discretized in intervals $t=1, …, T$ of eg. 1-minute length. Likewise, are tracks divided into blocks $b=1, …, B$. (There is of course an additional track structure).

For a given train “request” *r*, the different possible train movements are represented by a network in space and time. The nodes are time-stamped points along the tracks, such as stations or block boundaries. The arcs of the network can for example look like: “driving from *A* to *B* at time *t*, with acceleration in *A* and deceleration in *B* (i.e. a stop)” or “driving from *A* to *B* at time *t*, with acceleration in *A* and no deceleration in *B* (i.e. no stop)”. Each such arc occupies certain blocks under given times. There is also a fictitious start node connected to all possible starting nodes (in space and time).

Each train path (that is, a path through the network) provides benefits or revenues. Assuming that the benefits of each path are known, the problem is to find a combination of train paths that gives maximum revenue, without violating the track capacity.

We solved the problem through lagrangian relaxation of the capacity constraints, i.e. putting a price on capacity violations. For each value of the lagrange multipliers $λ=(λ\_{bt})$, we then get one shortest-path (SP) problem for each train request. For a given $λ$**-**value we get an over estimate of the optimal objective value (since we have relaxed constraints). The computed shortest paths provide supporting planes to the ‘dual’ objective function (i.e. the revenue as function of the multipliers). The dual problem is to minimize the dual objective, i.e. to find the best overestimate. We solved the dual problem iteratively (under the generation of the new shortest paths, i.e. supporting planes) with the help of a ' bundle ' method, where one puts on quadratic penalty on steps, in order not to rush away too far. On top of this, we need to construct integer solutions of those fractional we get from the solution process.

In the new study we intend to follow the same basic approach, but with some methodological improvements.,

The project has two distinct subprojects, each constituting a Master’s Thesis project.

1. Parallelized shortest-path calculations for trains.

(This part is suitable for a computer scientist (D) or a computer savvy engineering physicist (F).)

2. Development of master-routine with bundle method

(This part is suitable for an engineering physicist (F) or a theory-interested computer scientist (D).)

*Master’s Thesis Project 1, Parallelized shortest-path calculations*

This is the” lagrangian subproblem” solved in each iteration. It is also the computationally heavy part. That’s why we want to run on multiple processor cores, in order to bring down the total running time, which is critical. Thus we also want the code to be as efficient as possible. In some similar problems one has achieved almost linear speedup in the number of processors.

As hinted above, each train request has its own network, where each node has a time and a place label (e.g. a station, or a switchover between two blocks). The time labels imply that the network is acyclic.

The train has a starting and a final station. It also has a desired starting time, and a function describing how the revenue declines when one deviates from this desired starting time. Further there is a desired running time and a penalty function for deviating from that.

Due to the acyclicity of the network, one can solve the SP problem in one scan of the network. Moreover, one need not scan the whole network, since if the train gets too delayed, it will not be profitable.

The output of this subproject is the coverage of the blocks in time and space for the generated train paths.

We further want to study how the running time depends on the number of processors.

It also suitable that this subproject handles the representation and the updating of the Branch &Bound tree from Subproject 2.

*Master’s Thesis Project 2, Development of master-routine with bundle method integrality routine*

Here the aim is the development of a tailor-made bundle method as a master-routine.

For given supporting planes (i.e. SPs), the master routine calculates new multiplier values $λ$, sent to subproblem in part 1. This a QP (Quadratic Programming) problem with special structure, that we want to utilize for efficiency.

This subproject also has an integrality part that generates integer solutions based on the fractional ones, which bundle method gives. Here, we want to utilize a new technique, called rapid branching, where one heuristically dives down promising branches of the Branch & Bound tree, to find good integer solutions.

Both project parts can be said to be quite tough, and can be seen as an introduction to postgraduate studies. If the pilot study is successful, it is not unlikely that Doctor’s thesis projects are defined as a continuation.

*Contact*

PO Lindberg, VTI, Teknikringen 10, KTH Jan-Eric Nilsson, VTI, Teknikringen 10, KTH

polin@kth.se [jan-eric.nilsson@vti.se](file:///C%3A%5CUsers%5CASUS%5CDocuments%5CPO%5CProjects%5CJ%C3%A4rnv%C3%A4g%5Cjan-eric.nilsson%40vti.se)

*Reference*

U. Brännlund, PO Lindberg, A Nöu and J-E Nilsson (1998), Railway timetabling using langangian relaxation, *Transportation Science* **32** (4): 358-369