Optimisation Criteria

Maura Mazzarello - On AIR

Genova, 6th December 2007

Reference OA/OC/061207/D1

1. INTRODUCTION

The TMS optimisation model is based on the alternative graph representation of the train movements. In such model, how to solve (better, how to prevent) a conflict depends on local rules (e.g. which train is more delayed, which train has greater priority etc.). Avoiding a conflict corresponds to select one arc of an unselected pair of alternative arcs and to forbid the paired arc. In consequence of the selection, the order between two trains is fixed and also others precedence relations are decided in consequence of that.
Different methods to decide which arc has to be selected in order to optimize the rail traffic can be applied.
Particularly, in the CRS1 model different rules (heuristics) are available, but in the current implementation a fixed heuristic is applied. It was selected as the most promising rule during the pilot study, as this heuristics outperformed the others for the experiment characteristics.
Because the heuristic used could significantly influence the TMS performance, some effort needs to be spent to make explicit how the different heuristics work and perform in different situations (timetable, performance indicator, infrastructure,..).
This proposal addresses a requirement of higher configurability of the optimisation criteria available in CRS1 model.

2. THE ROLE OF HEURISTICS IN ALTERNATIVE GRAPH OPTIMIZATION

The scheduling algorithm in TMS minimises a suitable function of exit delays, acting both on train precedence relations at conflict points and on train routings.
Aim of the heuristics in the model is to find a feasible solution without exploring all the possible alternatives, by selecting in sequence the most promising ones and applying them.. Promising means: likely to reduce the objective function (a suitable function of exit delay). Such way, the scheduling algorithm is able to produce in a short time an optimised solution.

2.1. CLASSIFICATION OF THE HEURISTICS

With respect to the selection of the most promising decision (e.g. the order in which two trains must use a given track resource), the heuristics available in CRS1 model can be classified in three classes:

a) Local and causal: decisions are taken on a local basis (involving only the arrival time of trains in a given place) and in a causal way (decisions are ordered by increasing times). Such heuristics reproduce the normal flow of trains in the network, in which the first come is served. The optimization margin is small, because most decisions are often uniquely fixed.

b) Local and not causal: decisions are taken on a local basis (e.g. involving only the arrival time of trains in a given place) but they can be taken in any order. That means: the first decision may be taken for an event in the estimated future. That gives a wider margin for optimization, but not causal decision are taken on the basis of predicted (may be uncertain) data. Especially in heavy perturbed traffic conditions, it is possible to take a decision which is logically correct, but not so optimal when the actual situation changes.

c) Not local and not causal: decisions are taken on a not local basis (involving train behaviour in different points with respect to the conflict, typically the exit point) and ordered without any causality. Optimization margin are larger, because decisions can be taken foreseeing the consequences on the whole network (e.g. reduction of the global delay) and very good schedules can be found. However, all the involved data are predicted and so errors can occur, especially when train behaviour is unpredictable.

2.2. IMPORTANCE OF THE ORDER

When a decision is taken, every consequence of it must be derived, in order to keep the graph consistent. However, working in such a sequential way, the decision order is a key factor. A wrong decision at an early stage may lead to a not optimal schedule. So it is important to take earlier decisions that are more likely to be correct.

How to tackle with errors: errors in prediction are unavoidable in complex/perturbed traffic conditions. The only way to tackle with errors in prediction is to revise the schedule quite often, in order to verify if the decisions taken are still optimal. That means avoiding static optimal schedules, but applying a dynamic approach in which the optimum is reached by a sequence of data-adaptive schedules.

3. SELECTION OF “THE BEST” HEURISTIC

In CRS1 model <u>6 heuristics</u> are implemented. According to the classification in §2.1, the available heuristics can be grouped as follows:

- one heuristic of type a)
- two heuristics of type b)
- three heuristics of type c)

Besides, in the current CRS1 implementation each heuristic is sensible to train priorities.

In general heuristics of type c) works well in real cases on a statistical base (they outperform the others in most cases, but not always). Typically, when the train dynamics is far form predictable and large perturbations are possible, simpler heuristics might perform better, because the make less use of prediction.

The proposed activity aims at finding general criteria to match the type of the heuristic (hopefully the single heuristic) with different conditions.

4. THE OBJECTIVE FUNCTION

Producing a good schedule depends also on the objective function. Even when the heuristic is fixed, for specific trains we may guide the optimisation changing in a proper way the objective function (for instance, if the minimum delay is the heuristic applied, we can decide that the objective function doesn’t aim any more to reduce a delay higher than a given threshold for a train). The objective function can be slightly changed by weighting the single train delays in a given way. Actually CRS1 uses a customised weighting model defined in the pilot, which produced good results. This model can be made explicit in order to be modified by the dispatcher (within a given range of possible values).

5. CRITERIA FOR THE CHOICE

The choice of “the best” heuristic for a given traffic problem, represents a difficult task. So, the preliminary task to be performed is to make explicit and understandable the available heuristics, possibly with criteria for the choice, in order to present them as an option (with suggested defaults) to the dispatcher.
The following elements seem to be relevant for the choice:

i) traffic characteristics:
  - heavy/low traffic
  - traffic combination (types of trains, priorities of trains,…)
  - controlled/not controlled trains (%)

ii) disturbances:
  - driver co-operation
  - degradations
  - delays

iii) lay-out/routes characteristics:
  - which part (big/little) of the area different trains have in common
  - percentage of open tracks with respect to PPLGs

iv) objectives of the studies
  - max throughput
  - min delay
  - traffic smoothness

Other characteristics could be found. It can be observed that characteristics from i) to iii) gives an indication about the complexity of the scheduling problem.
The proposal includes activities to investigate these characteristics[1] in connection with heuristics and objective functions. The aim is to group “similar” characteristics and classify them. Then create cross-relations between characteristics and heuristics+objective function parameters.

---

[1] Varying the elements in iii) can be difficult by us. Could ProRail provide different “experiments” (different portions of the controlled area, different time tables,..)?

We expect that good indications can be reached only through experiments carried out in different conditions.

A good starting point for the analysis is the “complexity” of the problem. In TMS model the problem is represented by means of the alternative graph. As a consequence, a good indicator of the complexity of the problem seems to be the complexity of the alternative graph which represents the traffic problem. So, extracting numeric indicators of the graph “size” for each experiment could provide good indicators about the problems, useful to choose the most suitable heuristic.

5.1. GRAPH SIZE INDICATORS

The alternative graph complexity can be evaluated looking at a few quantities counting the main elements involved in graph building:

Number of nodes: it is related to the number of trains and to route discretisation, that means the distribution of control points along the train path. Given a fixed layout, the number of nodes increases linearly with the number of trains.

Number of fixed arcs: this number is higher than the number of nodes, including also all the arcs needed to represent entry/exit of trains and additional constraints, like fixed precedence relations, departures, etc. It grows linearly with the number of trains.

Number of alternative arcs: this number is strongly related to network topology, as an alternative arc pair is needed whenever two trains share the same track element. It is, in principle, a quadratic function of the train number, but the effective number is highly dependent on how a train interacts with each others.

From the above quantities we can derive two simple graph indicators, taking the ratio of the two arc counters with respect to the node counter:

fixed arcs / # nodes = incidence of constraints (excess of fixed arcs to nodes)
alternative arcs / # nodes = average number of interacting trains (with a given one).