A study of an incremental texture-based heuristic for the train routing and scheduling problem

Joaquín Rodriguez, Sonia Sobieraj

joaquin.rodriguez@inrets.fr, sonia.sobieraj@inrets.fr

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Outline

Rail traffic management - Scope

Rail Traffic managent problems

Off-line timetabling	$\longrightarrow$	hight-quality timetables
Real time traffic management	$\longrightarrow$	modify the timetables to reduce the impact traffic of incidents

Rail traffic management - Scope

Rail Traffic managent problems

Off-line timetabling	→	hight-quality timetables
Real time traffic management	→	modify the timetables to reduce the impact traffic of incidents

Rail traffic management - Scope

Real time traffic management

Geographical organisation :

- National control center
- Regional control centers
- Local control centers (e.g.stations, . . .)

Rail traffic management - Scope

Real time traffic management

Geographical organisation :

- National control center
- Regional control centers
- **Local control centers** (e.g.stations, ...)

Rail traffic management - Scope

Real time traffic management problem

A station traffic control center

Rail traffic management - Problem description

Real time traffic management problem

- Events
  - Technical failures, disturbances,
  - Additional trains, track maintenance works, . . .

  $\Rightarrow$ primary delays
- Interaction between train runs may cause propagation of primary delays

  $\Rightarrow$ secondary delays (knock-on delays)

Rail traffic management - Problem description

Real time traffic management problem

- Solve the problem :

$$\begin{cases} \min(\sum secondary\ \ delays) \\ s.t. \\ \text{Satisfy the safety and operational constraints} \\ \text{between train runs} \end{cases}$$

- Dispatcher decisions to reduce/avoid propagation :
  - change **train routes**
  - change **train schedules**

Rail traffic management - Motivation

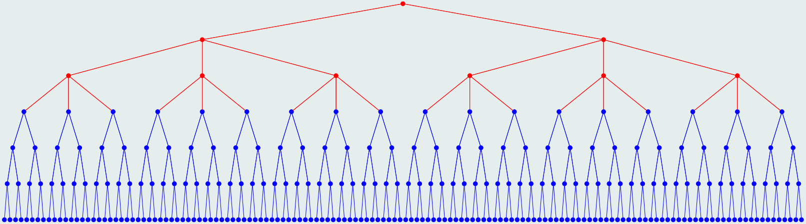
Resolution methods

Two-phase approach	Incremental approach
With global decisions : Train route allocation Train schedule	With local decisions : Track section allocation Track section movement schedule

Rail traffic management - Motivation

Decision tree : two-phase approach

(train route allocations , train schedules)

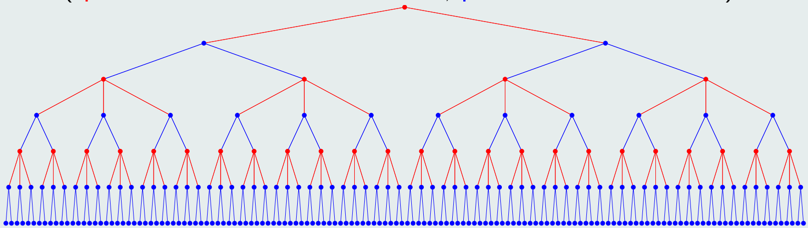


Complete search space exploration

Rail traffic management

Decision tree : incremantal approach

(partial train route allocations , partial train schedules)



Complete search space exploration

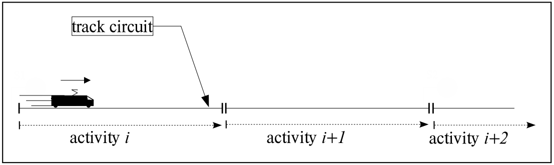
Rail traffic management - Motivation

Objectives

- New heuristic resolution method based on local decisions,
- Compare with a previous resolution method based on global decisions.

Constraint Based Scheduling model

- Our model is based on **schedule theory** :
  The real time traffic management problem is a kind of «joint **resource allocation** and **scheduling** » problem
- A train is a «job», i.e. a sequence of «activities»,
- Activities require track section «ressources».



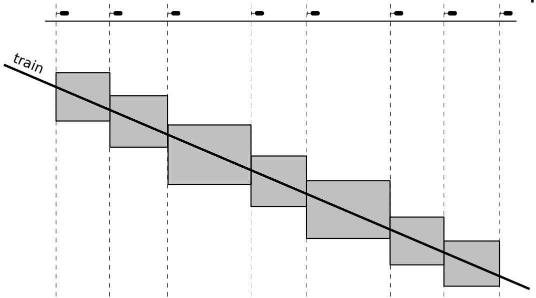
Constraint Based Scheduling model

Model

Train movements on track sections	$\mapsto$	Activities
Track sections	$\mapsto$	Unary Resources
Opposite direction conflicts	$\mapsto$	State Resources
Alternative routes	$\mapsto$	Resource constraints
Trains schedule, Block/ Interlocking system	$\mapsto$	Temporal constraints

Constraint Based Scheduling model

Time over distance diagram

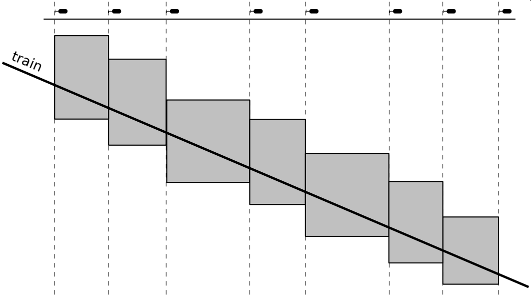


Temporal constraints :

- Signal watching time,
- Clearing time,
- 2 aspects signalling

Constraint Based Scheduling model

Time over distance diagram



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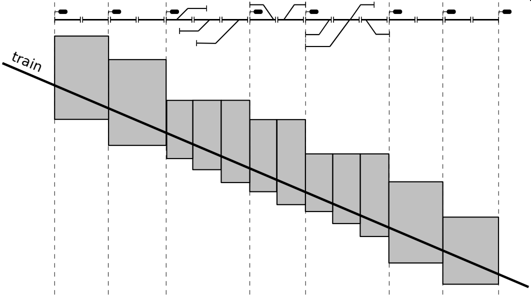
Constraint Based Scheduling model

Time over distance diagram



Temporal constraints :

- Signal watching time,
- Clearing time,
- 2,3,. . . aspects signalling
- Sectional route release (interlocking)

Resolution methods

Solving a joint scheduling and resource allocation problem :

Two phases approach - TPH

1. **Complete** resource allocation
2. **Complete** scheduling

Incremental approach - INC

Repeat

(**Partial** resource allocation)
or (**Partial** scheduling)

Until a complete solution is found.

Resolution methods

Two phases approach - TPH

Algorithm :

1. Assign routes to all trains
2. Schedule all activities of trains («Rank» algorithm of Ilog Scheduler)
3. Set the time variables of activities of trains to the earliest value

Resolution methods

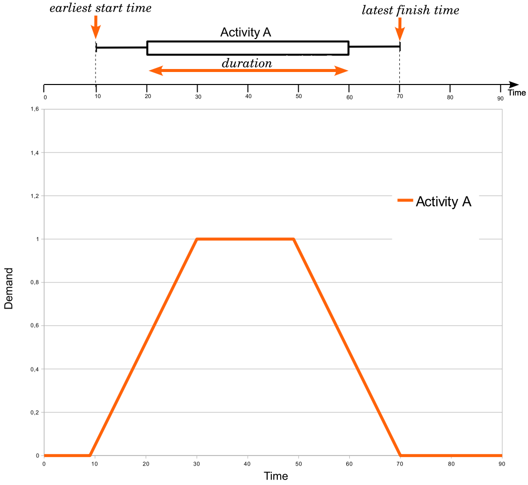
Incremental approach - INC

Algorithm :

1. Identifies a resource R with the **critical time point**,
2. Let A,B two unsequenced activities which require R on the critical time point,
3. Let C an activity which requires R on the critical time point and that still have alternative resources,
4. Choose between :

$$(A \prec B) \text{ or } (B \prec A) \text{ or }$$
$$(\text{resource}(C) = R) \text{ or } (\text{resource}(C) \neq R) \text{ .}$$

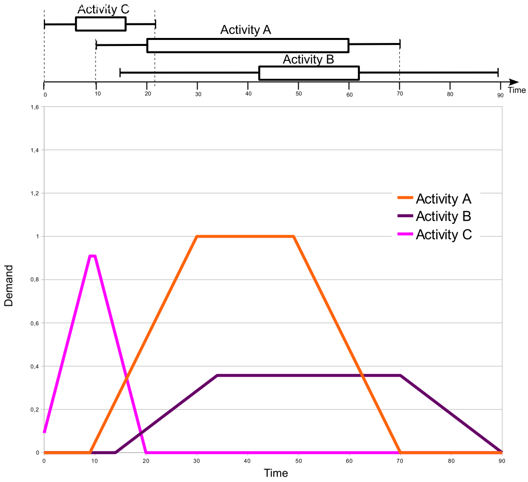
Resolution methods - Critical time point



Example of calculation of the contention for a resource R :

- Individual demand of an activity A

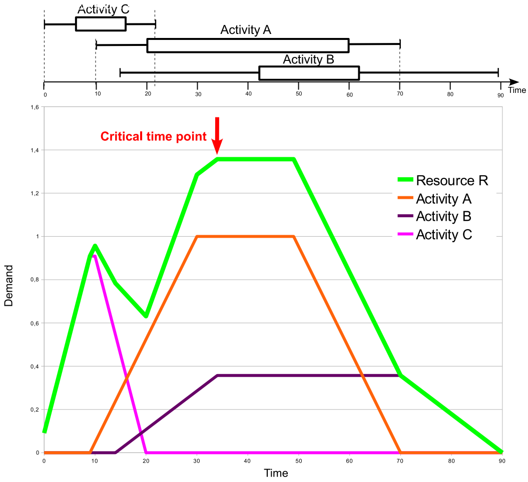
Resolution methods - Critical time point



Example of calculation of the contention for a resource R :

- Individual demand of an activity A, B and C

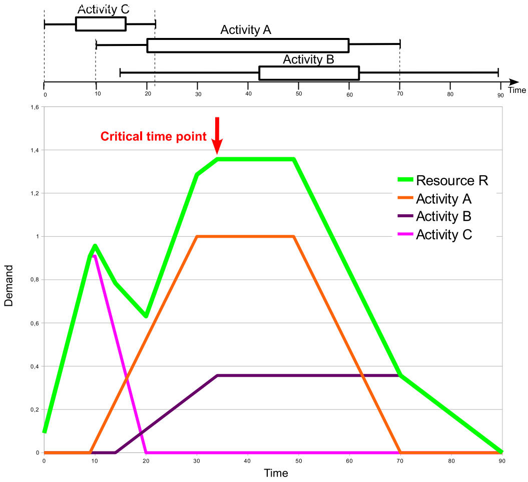
Resolution methods - Critical time point



Example of calculation of the contention for a resource R :

- Individual demand of an activity A, B and C
- Aggregated demand as a measure of the contention for R

Resolution methods - Critical time point

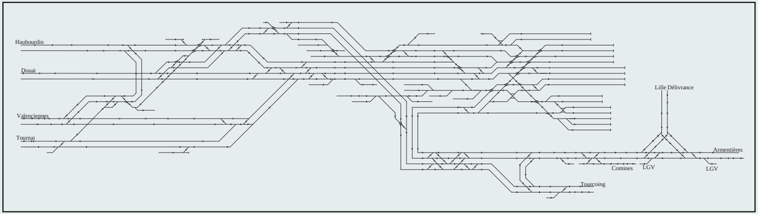


Example of calculation of the contention for a resource R :

- Individual demand of an activity A, B and C
- Aggregated demand as a measure of the contention for R
- The curves are updated during search to get algorithms that implement **dynamic analyses** («texture measurement»)

Experiments

The layout of the Lille-Flandres station



7 lines, 17 platforms
Running distance ≈ 4 kilometers.
Running time ≈ 6 minutes.

Experiments

Instance problems considered

Set of instance problems :

- Select a peak period with 40 trains,
- Alternative routes per train < 30,
- Instance L18 : compress the train schedule from 3600s to 2300s,
- Generate L17-L1 by removing 2 trains.

Inst.	$\|T\|$	nb var.	nb ct.
L1	6	2279	2978
L2	8	4110	5382
L3	10	4702	6113
L4	12	6035	7600
L5	14	8506	10648
L6	16	9594	11977
L7	18	10645	13090
L8	20	11754	14323
L9	22	13225	16065
L10	24	13735	16641
L11	26	14860	17859
L12	28	15953	19094
L13	30	16869	20060
L14	32	17788	20971
L15	34	18599	21763
L16	36	19776	22923
L17	38	20908	24096
L18	40	22872	26130

Experiments

Configurations considered in the study

NoSRCt + TPH : Model **without** the state resource constraints (NoSRCt) and the two-phase resolution method (TPH),

SRCt + TPH : Model **with** the state resource constraints (SRCt) and the two-phase resolution method,

SRCt + INC : Model **with** the state resource constraints (SRCt) and the incremental resolution method.

Stop condition : 180 s CPU time limit (including setup and preprocessing of data)

Experiments

Results

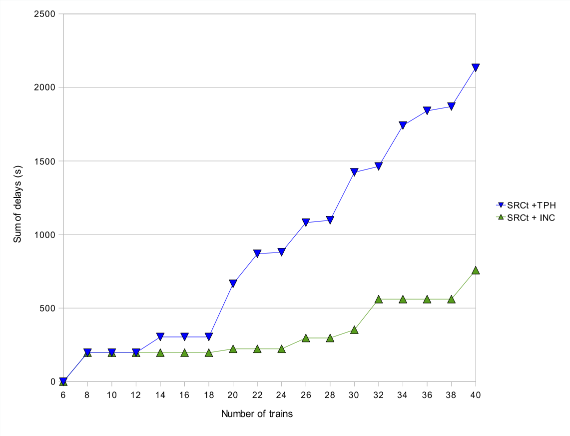
inst.	$\|T\|$	NoSRCt + TPH BS	NoSRCt + TPH CPU	SRCt + TPH BS	SRCt + TPH CPU	SRCt + INC BS	SRCt + INC CPU
L1	6	0	0.88	0	0.98	0	1.04
L2	8	197	1.12	197	1.59	197	1.68
L3	10	197	1.3	197	1.96	197	1.84
L4	12	197	6.18	197	11.36	197	2.38
L5	14	304	1.25	304	2.91	197	3.33
L6	16	304	6.43	304	5.42	197	3.73
L7	18	304	128.61	304	31.54	197	4.04
L8	20	-	-	665	139.51	223	4.33
L9	22	-	-	869	10.86	223	4.94
L10	24	-	-	880	51.52	223	9.03
L11	26	-	-	1081	155.32	297	14.76
L12	28	-	-	1097	153.93	297	19.52
L13	30	-	-	1423	4.1	353	53.8
L14	32	-	-	1463	170.8	561	15.31
L15	34	-	-	1741	4.58	561	16.03
L16	36	-	-	1841	5.06	561	17.41
L17	38	-	-	1870	5.44	561	19.59
L18	40	-	-	2133	7.13	758	26.53

- (NoSRCt+TPH) improves the greedy solution for 7 instances and find no solution for the other instances
- (SRCt+TPH) improves the greedy solution for 14 instances
- (SRCt+INC) gives the best results.

Experiments

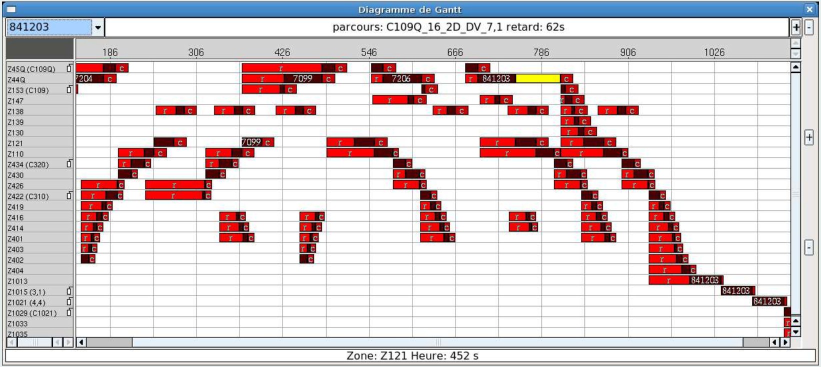
Two-phase method (TPH) versus incremental method (INC)

Sum of delays



Experiments

The Gantt chart for a solution



Conclusion

- A model of the **train routing and scheduling problem**,
- Our model is able to consider **a large number of technical and commercial characteristics** drawn from real situations.
- A two-phase method has been compared with an **incremental method**.
- The incremental method shows very promising results.
- Futur work :
    - Apply the heuristic to local search methods,
    - Link the model with a speed coordination module to consider train speed profiles.