A cooperative framework between optimization & simulation to address on-line re-scheduling problems.

RailZurich2009

3rd International seminar on Railways Operations Modelling and Analysis

Engineering and Optimisation Approaches

February 11 - 13, 2009

Zurich, SWITZERLAND

donner au train des idées d'avance

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A framework
to address on-line re-scheduling problems.

A major challenge today is to study efficient tools to help experts' decisions in the rescheduling process of tomorrow.

The topic of this presentation is not about optimization technics nor methods but about how an innovative framework can help to develop an operational tool.

(Laurent Gély, Damien Feillée, Gilles Dessagne)

Agenda

- The re-scheduling problem, Simulation & Optimization.
- Why a cooperative framework?
- A chronological description of the new framework.

Essentials about Real-Time Re-scheduling, Simulation, and Optimization.

- Essentials
  - An overview of the re-scheduling problem,
  - About Simulation,
  - About Optimization.
- Why a new framework?
- A Chronological description.

An overview of the Re-scheduling problem.

Aim : on line re-computing of schedule following perturbations.

Objective : minimizing disturbances.

Main challenges:

- Tractable = fast calculations,
- Operational solution = must be immediately applied on the field,
- … (good solution)

About Simulation

What is simulation?

- A simulator reproduces reality,
- Microscopic description,

But

- Does not take decision,
- Is deterministic.

Different Uses:

- Simulation on a large scope (forecasting),
- Local simulations may help to calculate *on the fly* dynamic data:
  e.g. precise spacing between two trains with varying speeds, non-linear interactions (accelerations, ...)

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About Optimization

Optimization aims

- Seek to enhance the quality of a solution (i.e. a set of decisions), in regard of an objective
- Possible solutions domain is restricted through constraints,
- Macroscopic description (or small area).

Requirements:

- Accurate data,
- Adequate Size of the problem
  (combinatorial explosion)

Why should we develop a new framework combining optimization and simulation?

- Essentials
- Why a new framework?
  - Applications @ SNCF
  - Operational requirements
  - A new framework is needed
- A chronological description

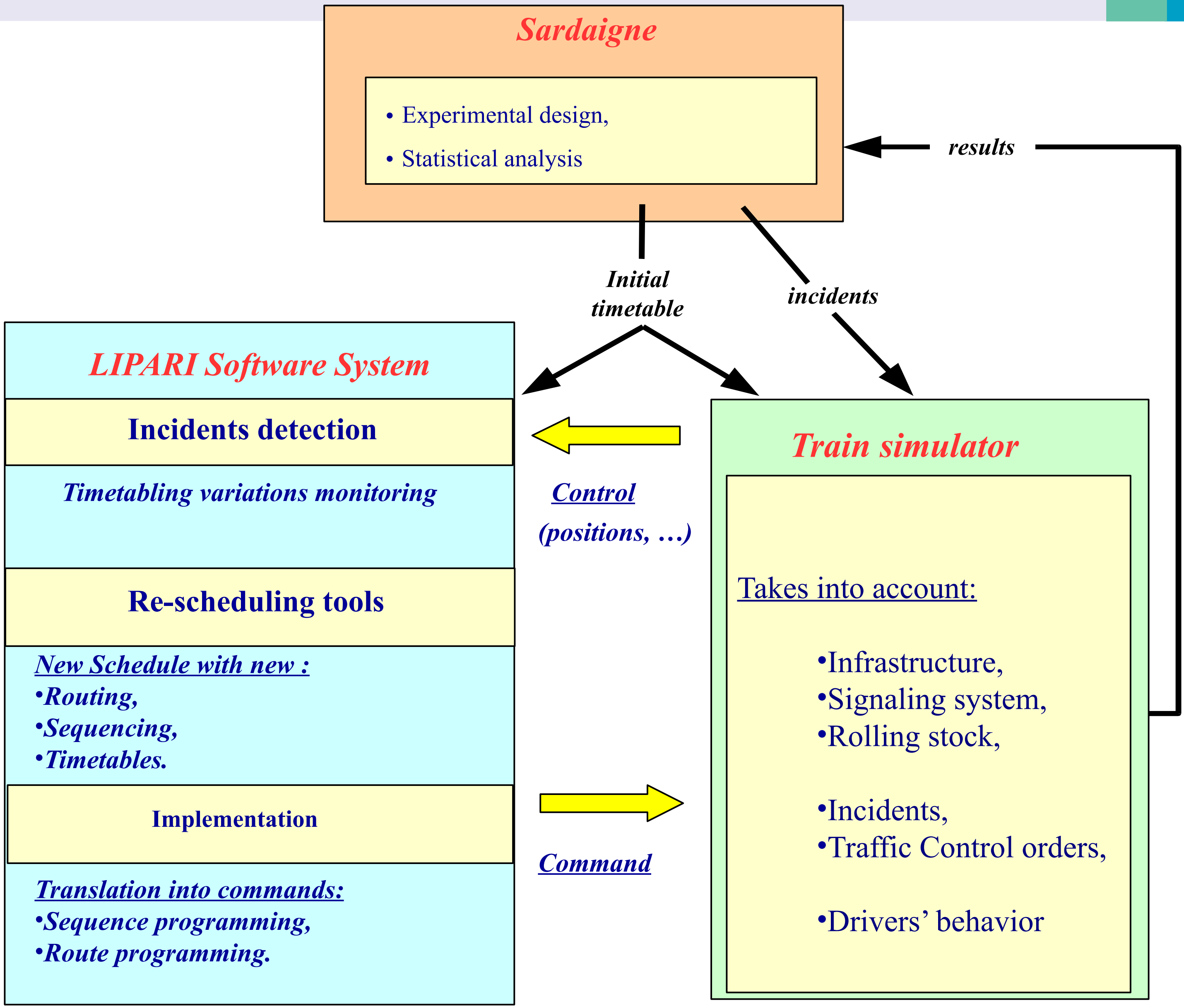
Applications @ SNCF

A 1rst framework using Simulation & Optimization

SNCF has developed off-line re-scheduling prototypes working within a train simulator,

- Wide range of problem: incidents that cover from large area to local studies (around a bottleneck)
- This allowed us to study a global framework for the future operational tool dedicated to reschedulling.

Software system implementation (off-line prototype)



Operational requirements

<u>What did we learn?</u>

- Data (dynamic & static),
- Forecast-Projection (conflicts detection, anticipate the duration of decision process, give an incumbent)
- Analysis (geographical area & time window to consider)
- Validation (precise & microscopic)

A cooperative framework toward an operational tool.

Assume we have:

- Efficient optimization,
- Rapid simulation.

Yet, what we need is to develop
an operational on-line re-scheduling tool.

A new Framework:

- Faces poblems described above,
- Uses synergies (simulation + optimization).

Description of a new framework combining optimization and simulation.

- Essentials
- Why a new framework?
- Description of a new framework
  - List of important points
  - A chronological description

Framework's most important points.

1. Continuous monitoring of informations from sensors on the field (control),
2. Real-time projection of the railway system state –without explicit actions- (simulation),
3. Automatic Incident Detection,
4. Analysis and forecast: adequate area and time-window to consider (statistical tools),
5. Define an adequate (macroscopic) level of description for optimization,
6. Translation into a mathematical problem,
7. Resolution (optimization),
8. Re-interpretation of the solution to get back to a microscopic level (precise description),
9. Precise checking by the railway simulator,
10. Human validation,
11. Automatic Commands' Dispatching.

Continuous Monitoring

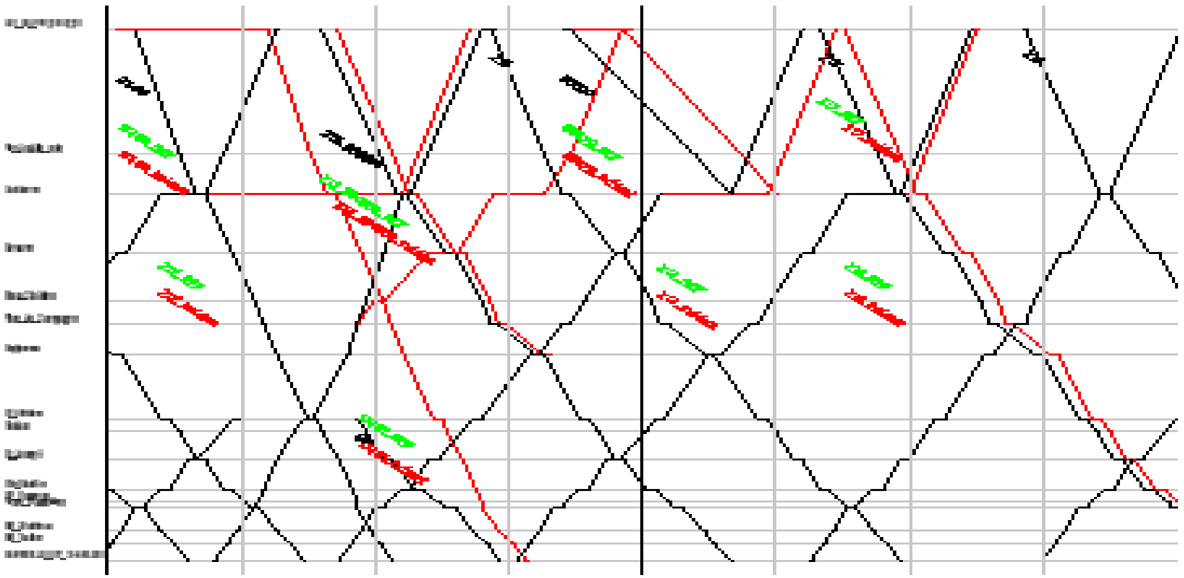
Continuous monitoring of informations coming from sensors on the field (control system & information system),

Very frequently, or every time new informations differs from theoretical schedule: run a projection.

2- Projection:
a real-time simulation of the railway system.

Aim: simulates precisely the predictible evolution of the railways' system, following perturbations.

- Without Decisions.
- This allows automatic conflict detection



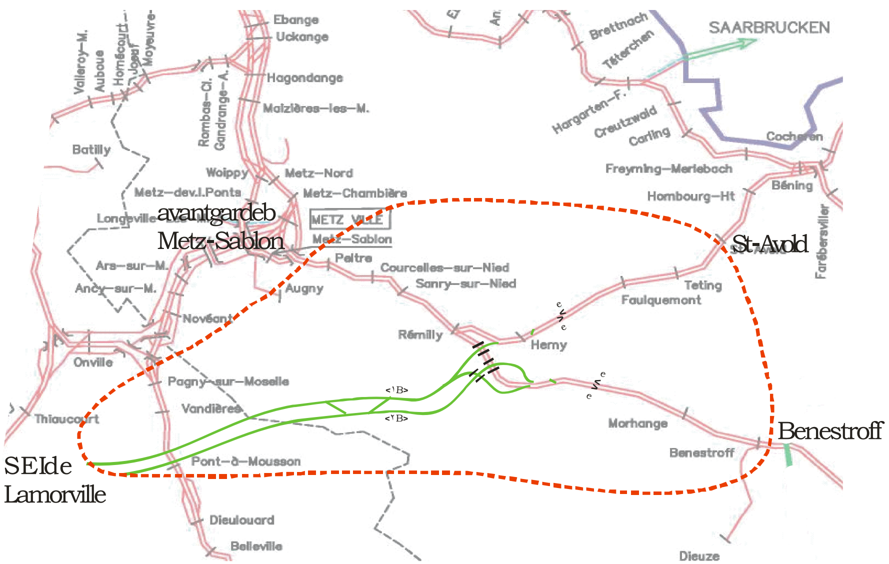
Pre-Analysis
(from raw data to fine tuned optimization's parameters)

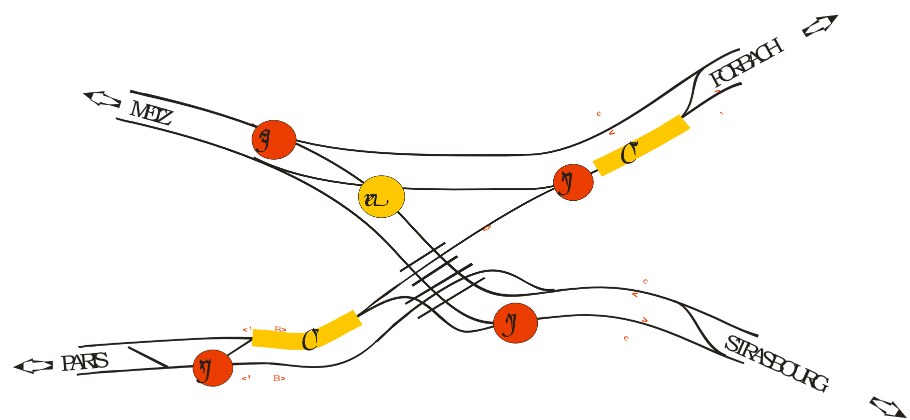
Statistical tools must determine:

- Incident duration & impact

In order to decide

- Geographical area & Time-window to consider
- Adequate level of description (micro -> macro)





Optimization

- A mathematical model is generated
  (macroscopic description!)

- Projection is used as incumbant -> a local search.

  Solution consists of:
  - New decisions
  - New (macroscopic) schedule

NB: methods & algorithms may vary with the size of the incident, however the framework will remain unchanged.

Post-Analysis
(A translation into the microscopic level)

The re-scheduling problem seeks for a precise solution.

Macroscopic schedule

-> Microscopic schedule + speed orders, ...

This translation is *not unique!*

A second goal could be enhanced:

robustness, energy efficiency?

Validation via simulation

The new solution must be tested precisely.

New orders are given to the simulator: we must check that the calculated schedule will be tractable on the field.

If the simulation reproduces what was calculated: ok.

Else

- If the deviation is small: go back to the post-analysis step or accept it.
- Else: go back to the pre-analysis step with new informations.

Human Validation & Command

The expert can **accept/modify/refuse** the solution.

(a new simulation permits to valid new modifications)

When the solution is finalized, commands are dispatched automaticly through the command system.

Conclusion

Simulation (alone) permits a projection and a precise checking of the solutions and may answer the problem of lack of (dynamic) data.

Moreover synergies must be used to fine-tune optimization parameters, and accelerate the resolution process.

Paradox-> more precision within less time: we must use projection as incumbant and all the possible synergies to face the real problem.

Simulation & optimization must be combined
to face efficiently on-line problems!

Thank you for your attention!

more on:

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