Simulation of Urban Train Systems with Regulation

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Regulation

Metro operators are committed to quality of service: punctuallity (w.r.t. fixed **schedules**), regularity of trains, nb. users transported….

Incidents cause **delays** in trains operation. Small to medium delays can be recovered by application of **regulation** techniques:

- increase trains speed,
- reduce dwell times…

Objectives

Regulation is largely automated: several **algorithms** can be used

But:

- Metro architecture influences performance
- Regulation is part of the design of a line
- QOS objectives differ for each project
- No a priori clue to choose a regulation algorithm or set its parameters

Need for evaluation & early decision tools

Contribution of SUMO

- Use of formal methods and concurrency models to **evaluate and compare** performance of regulation algorithms
- bunching avoidance
  ≡
  Optimal control in feedback loops
- Development of simulation tools

Industrial Context

Joint research lab between

INRIA and **ALSTOM**

Project P22

Regulation Policies in Urban Rail Systems

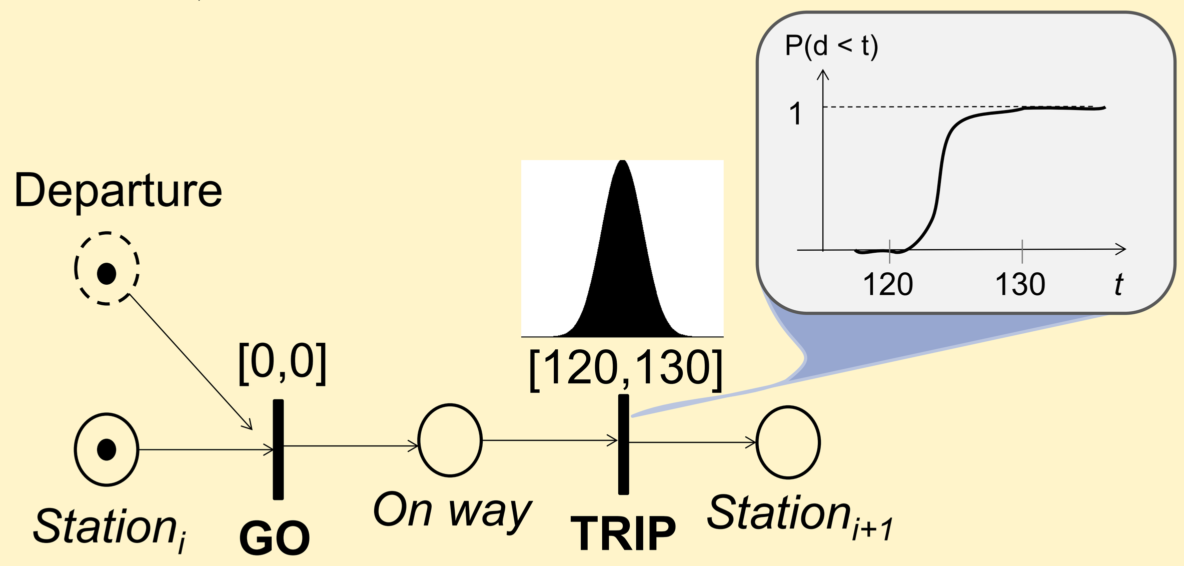
CIFRE Grant (2015-2018)

Ongoing transfer of results to ALSTOM

SIMSTORS[3,4]

A simulator for regulated train systems.
The heart of the software is a variant of **Stochastic Time Petri nets**[2]

- with ad-hoc semantics, and
- random distributions over trip times, dwell times, and incidents



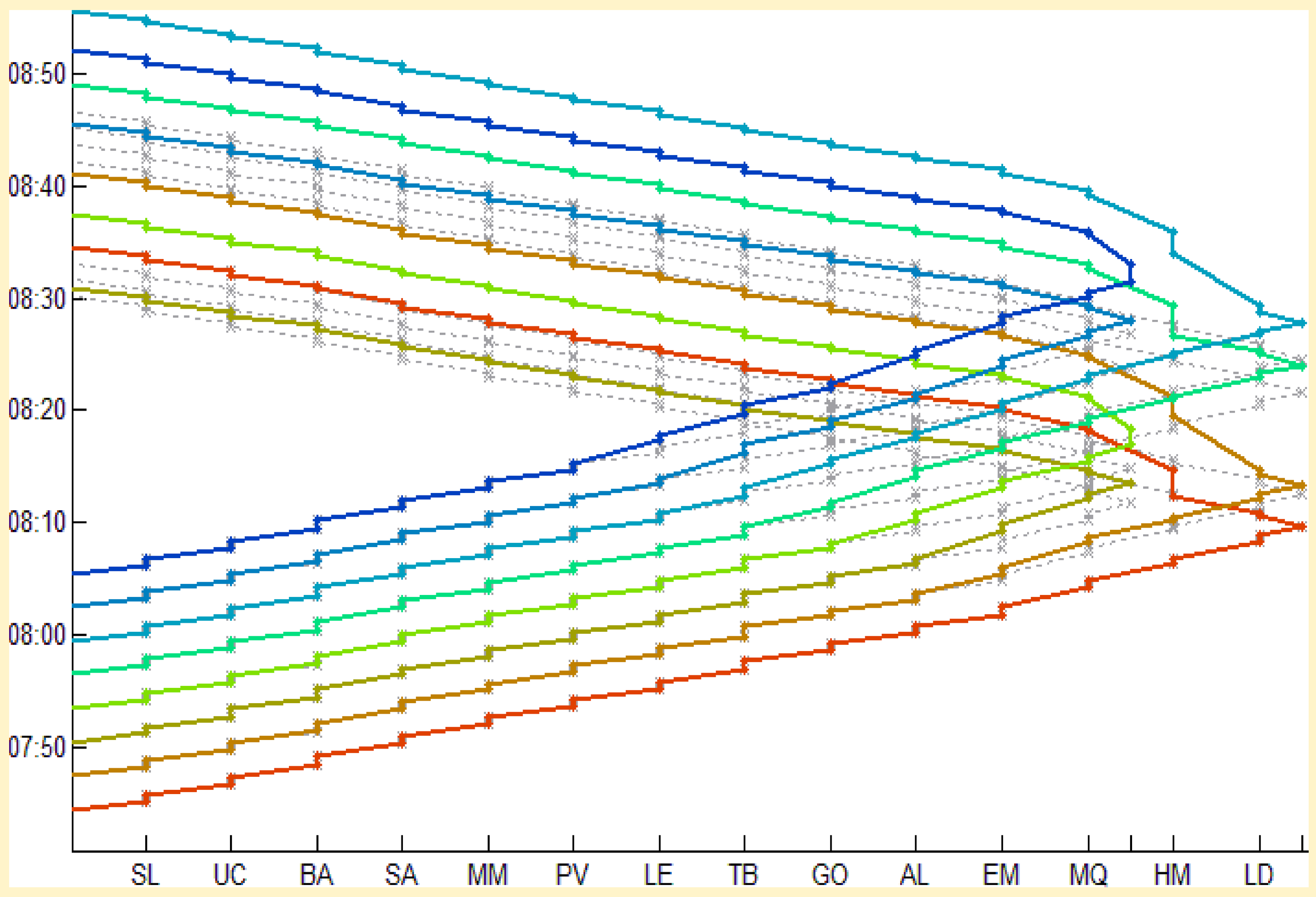
Results

- A **formal** design framework
- A fully operational **simulator** : SIMSTORS
  - case study: **Santiago Line 1** with early recovery regulation algorithm
  - Fast **symbolic** simulation:

4 hours of operation/50 trains/24 stations in 19s.

- Ongoing transfer at ALSTOM

- Success story for a concurrent stochastic timed DES model



Train trajectories obtained with SIMSTORS (Santiago L1, space-time diagram)

Future Directions

- Validation of the model with complex scenarios, multiple regulation algorithms
- Finer simulation of train interactions in interstation zones
- From performance evaluation to advice on best strategy to apply
- Optimal control w.r.t. quality criteria
- Application for planning

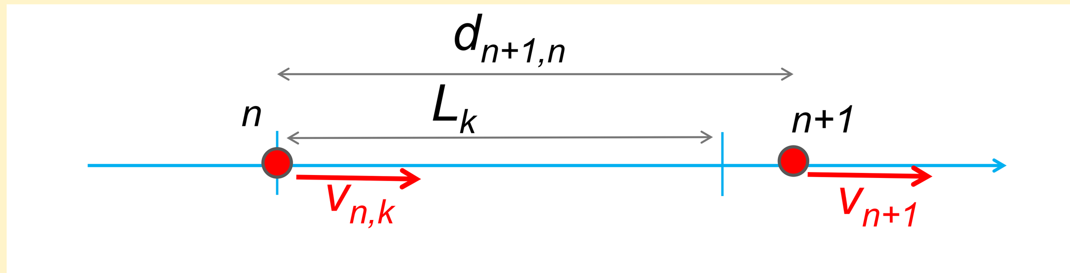
T-Plan

Adaptation of bus **bunching avoidance**[1] techniques to urban train systems.

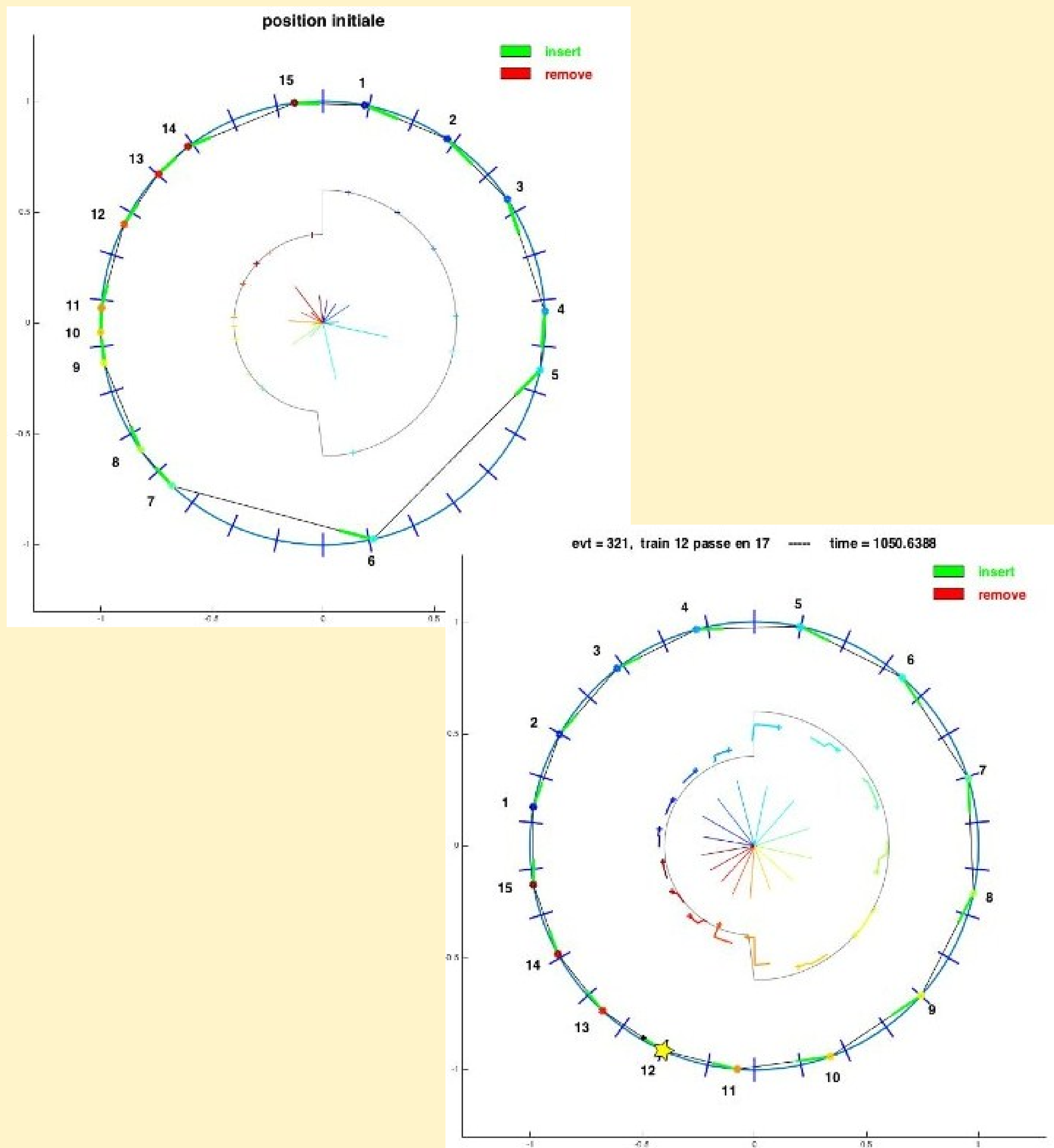
Regulation seen as **event based control**

Simplified problem: ring topologies

Objective: equalize headways above a threshold h_{min}



Optimal command ≡ optimal speeds



Headway equalization on ring topologies

Future Directions

- Complex topologies: forks, shuffled lines, insertion, extraction…
- Toward higher-level control, directed by objectives (rescheduling of missions, partial line closures, fast train extraction...)

References

[1] C.F. Daganzo, Y. Xuan, J. Argote, *Dynamic bus holding strategies for schedule reliability: optimal linear control and performance analysis.* Transportation Research Part B: Methodological, 45(10):1831–1845, 2011.

[2] A. Horváth, M. Paolieri, L. Ridi, E. Vicario, *Transient analysis of non-markovian models using stochastic state classes.* Perform. Eval., 69(7-8):315–335, 2012.

[3] K. Kecir, *Contrôle optimal d'un système ferroviaire complet*, Mémoire de master, Univ. Toulouse III–Paul Sabatier, 2014.

[4] L. Hélouët, K. Kecir, *Realizability of Schedules by Stochastic Time Petri Nets with Blocking Semantics*, (submitted), 2016.