Optimal RErouting Strategies for Traffic mangEment (ORESTE)

Guillaume Costeseque

Inria Sophia Antipolis Méditerranée

San Francisco, May 11, 2015

Outline

Outline

1. Associated Team ORESTE
2. Ramp-metering
3. Optimal re-routing
4. Perspectives

Associated Team "ORESTE"

ORESTE (Optimal REroutING Strategies for Traffic mangEment) is an associated team between Inria team ACUMES (ex OPALE) and the Connected Corridors project at UC Berkeley.

- Paola Goatin (PI)
- Maria Laura Delle Monache
- Guillaume Costeseque

- Alexandre Bayen (PI)
- Jack Reilly
- Samitha Samaranayake
- Walid Krichene
- Nikolaos Bekiaris-Liberis

Other fundings:

- ERC Starting Grant TRAM3
- France Berkeley Fund

ORESTE project goals

- Optimize traffic flow in corridors
  - ramp metering
  - re-routing strategies
- Modeling approach:
  - macroscopic traffic flow models
  - discrete adjoint method for gradient computation

Outline

Numerical Results: case study

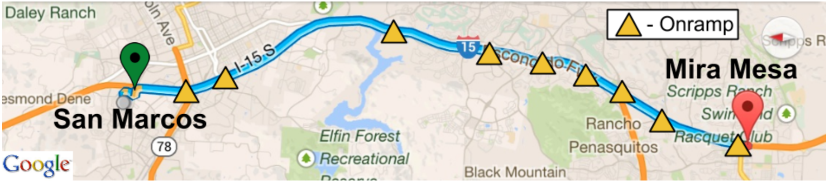


Figure: I15 South, San Diego: 31 km

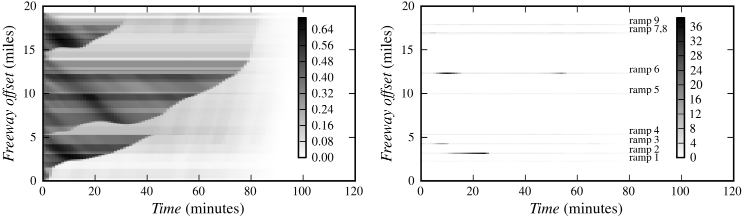
$N = 125$ links

$M = 9$ onramps

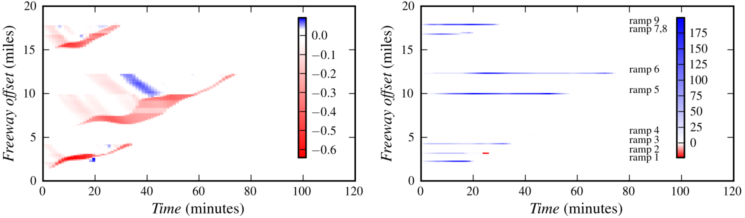
$T = 1800$ time-steps

$\Delta t = 4$ seconds (120 minutes time interval)

Numerical Results



Density and queue lengths without control



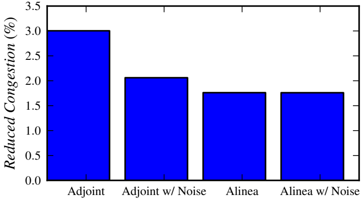
Density and queue difference with control

Model Predictive Control

Performance under noisy input data: MPC loop

- initial conditions at time t and boundary fluxes on T_h (noisy inputs)
- optimal control policy on T_h
- forward simulation on $T_u \leq T_h$ using optimal controls and exact initial and boundary data
- $t \to t + T_u$

Comparison with ALINEA (local feedback control without boundary conditions)



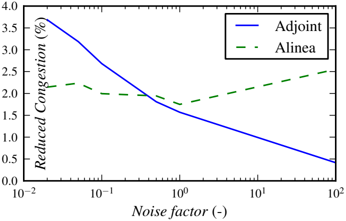


Figure: Congestion reduction and noise robustness

Outline

Application to optimal re-routing

System Optimal Dynamic Traffic Assignment problem with Partial Control:

- Multi-commodity flow accounting for *compliant* and *non-compliant* users
- Full Lagrangian paths known for the controllable agents
- Knowledge of the aggregate split ratios for the non-controllable (selfish) agents.

Goal: Control compliant users to optimize traffic flow

System Optimal Dynamic Traffic Assignment problem with Partial Control:

- Multi-commodity flow accounting for *compliant* and *non-compliant* users
- Full Lagrangian paths known for the controllable agents
- Knowledge of the aggregate split ratios for the non-controllable (selfish) agents.

Goal: Control compliant users to optimize traffic flow

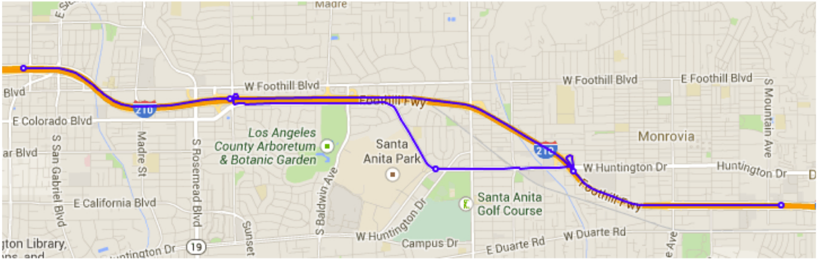


Figure: I210 with parallel arterial route, Arcadia (13 km)

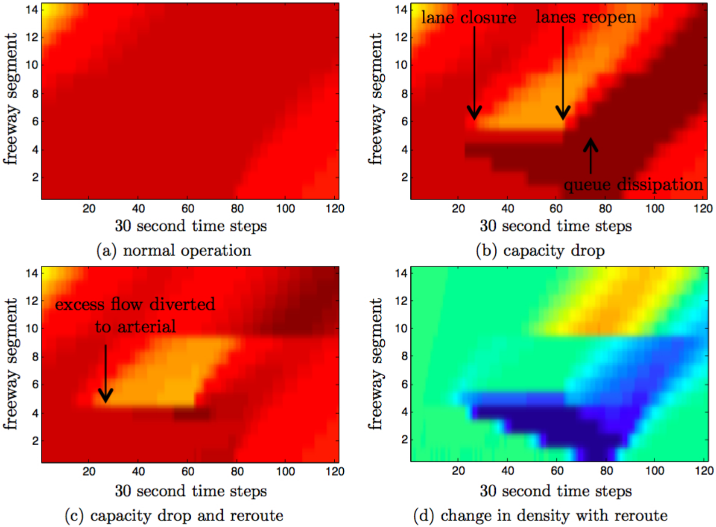
$N = 24$ links

1 hour time-horizon

$\Delta t = 30$ seconds

Numerical Results

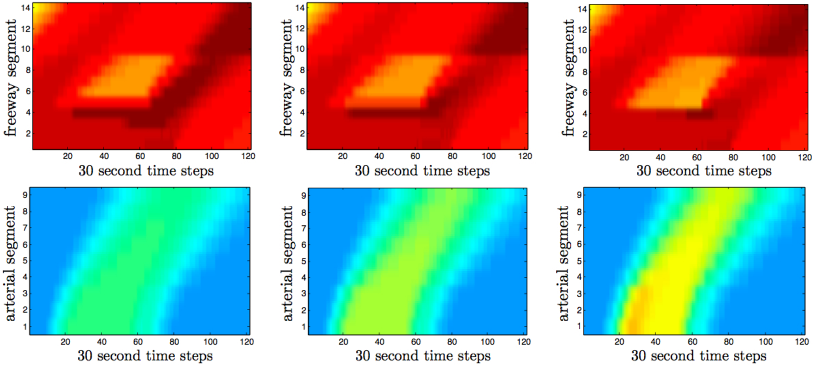
50% capacity drop between min 10 and min 30



(a) normal operation (b) capacity drop (c) capacity drop and reroute (d) change in density with reroute

Numerical Results

Arterial capacity used:



(a) 40% of arterial capacity (b) 50% of arterial capacity (c) full arterial utilization

Output

Journal papers

[J1] M.L. Delle Monache, J. Reilly, S. Samaranayake, W. Krichene, P.Goatin and A. Bayen. *A PDE-ODE model for a junction with ramp buffer*, SIAM J. Appl. Math., 74(1) (2014), 22-39.

[J2] J. Reilly, S. Samaranayake, M.L. Delle Monache, W. Krichene, P. Goatin and A. Bayen. *Adjoint-based optimization on a network of discretized scalar conservation law PDEs with applications to coordinated ramp metering*, J. Optim. Theory Appl., in review.

[J3] S. Samaranayake, W. Krichene, J. Reilly, M.L. Delle Monache, J.B. Lespiau, P. Goatin and A. Bayen. *Discrete-time system optimal dynamic traffic assignment (SO-DTA) with partial control for horizontal queuing networks*, Operations Research, in review.

Conference proceedings

[C1] S. Samaranayake, J. Reilly, W. Krichene, M.L. Delle Monache, J.B. Lespiau, P. Goatin and A. Bayen. *Discrete-time system optimal dynamic traffic assignment (SO-DTA) with partial control for horizontal queuing networks*, 2015 American Control Conference, Chicago, IL.

PhD thesis

- M.L. Delle Monache. *Traffic flow modeling by conservation laws*, UNS, 2014.
- J. Reilly. *Security of Freeway Traffic Systems: A Distributed Optimal Control Approach*, UC Berkeley, 2014.
- S. Samaranayake. *Routing strategies for the reliable and efficient utilization of road networks*, UC Berkeley, 2014.

Outline

Perspectives

- 3-years renewal just obtained for:
  - General well posed junction models
  - Variational approach based on Hamilton-Jacobi equations
  - User equilibrium
  - Lagrangian controls based on autonomous vehicles.
- Members:
  - **Inria**: P. Goatin, G. Costeseque
  - **UC Berkeley**: A. Bayen, F. Belletti, C. Wu
  - **Rutgers U** (partner): B. Piccoli, M.L. Delle Monache
- 2015: IPAM (UCLA) workshop "Mathematical Foundations of Traffic", part of the 3-months IPAM program on "New Directions in Mathematical Approaches for Traffic Flow Management",