

Model predictive control of large-scale urban networks via perimeter control and route guidance actuation

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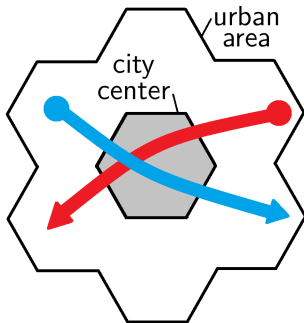


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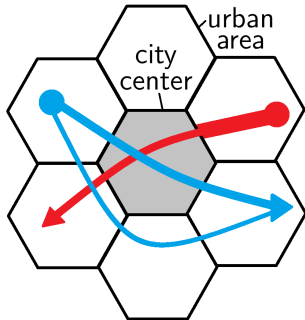
Motivation

Problem: Congestion



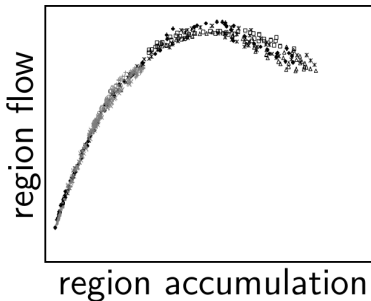
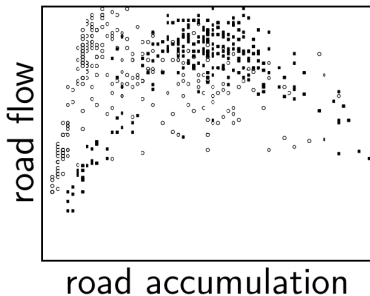
Center congested, network underused.

Solution: Control



Manipulate vehicle flows to use network efficiently.

Macroscopic fundamental diagram (MFD)¹



$$\underbrace{G_i(n_i(t))}_{\substack{\text{trip completion} \\ \text{flow (veh/s)}}} = a_i n_i^3(t) + b_i n_i^2(t) + c_i n_i(t)$$

$n_i(t)$: accumulation (veh)

¹Nikolas Geroliminis and Carlos F Daganzo. *Transportation Research Part B: Methodological* 42.9 (2008), pp. 759–770.

Spatial partitioning²

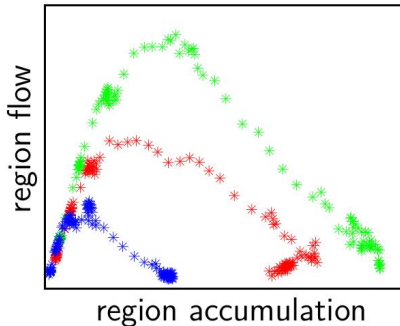
network map
(accumulations)



network map
(partition)



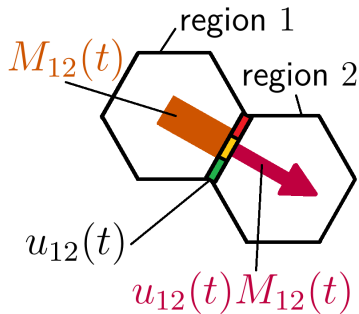
region MFDs



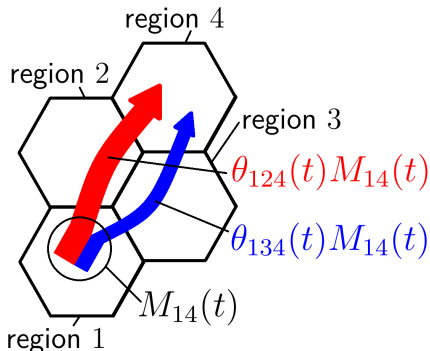
²Yuxuan Ji and Nikolas Geroliminis. *Transportation Research Part B: Methodological* 46.10 (2012), pp. 1639–1656.

Actuators

1) Perimeter control³



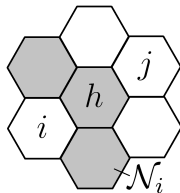
2) Route guidance⁴



³Nikolas Geroliminis, Jack Haddad, and Mohsen Ramezani. *IEEE Transactions on Intelligent Transportation Systems* 14.1 (2013), pp. 348–359.

⁴Mohammad Hajiahmadi et al. *16th International IEEE Conference on Intelligent Transportation Systems-(ITSC)*. IEEE. 2013, pp. 1022–1028.

MFDs network model⁵



$$\dot{n}_{ij}(t) = \underbrace{q_{ij}(t)}_{\text{inflow demand}} + \underbrace{\sum_{h \in \mathcal{N}_i^j} M_{hij}(t)}_{\text{inflow}} - \underbrace{\sum_{h \in \mathcal{N}_i} M_{ihj}(t)}_{\text{outflow}}$$

$$M_{ihj}(t) \triangleq \underbrace{u_{ih}(t)}_{\text{perimeter control}} \underbrace{\theta_{ihj}(t)}_{\text{route guidance}} \frac{n_{ij}(t)}{n_i(t)} \underbrace{G_i(n_i(t))}_{\text{trip completion flow}}$$

⁵Mehmet Yildirimoglu, Mohsen Ramezani, and Nikolas Geroliminis. *Transportation Research Part C: Emerging Technologies* 59 (2015), pp. 404–420.

Model predictive control (MPC)

$$\text{minimize}_{\mathbf{u}_{ih}(\cdot), \mathbf{\theta}_{ihj}(\cdot)} \int_t^{t+T} \sum_{i \in \mathcal{R}} n_i(\tau) d\tau$$

$$\text{subject to } \forall i, j \in \mathcal{R} :$$

$$n_{ij}(t) = \hat{n}_{ij}(t)$$

$$\forall \tau \in [t, t+T] :$$

MFDs network model

$$0 \leq n_{ij}(\tau), \quad n_i(\tau) \leq n_{i,\text{jam}}$$

$$u_{\min} \leq \mathbf{u}_{ih}(\tau) \leq u_{\max}, \quad \forall h \in \mathcal{N}_i$$

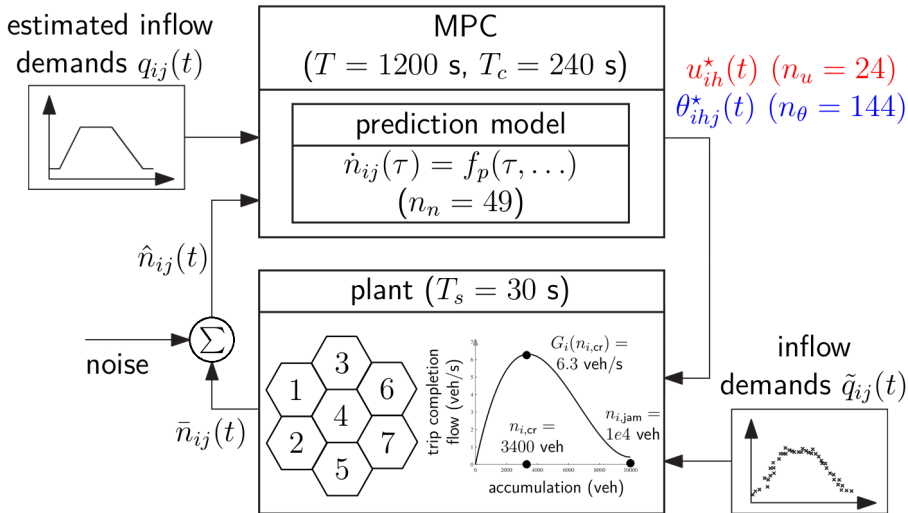
$$0 \leq \mathbf{\theta}_{ihj}(\tau) \leq 1, \quad \forall h \in \mathcal{N}_i$$

$$\sum_{h \in \mathcal{N}_i} \mathbf{\theta}_{ihj}(\tau) = 1$$

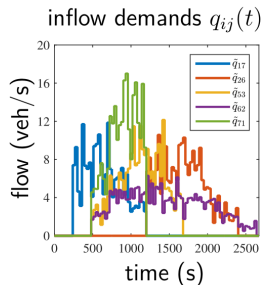
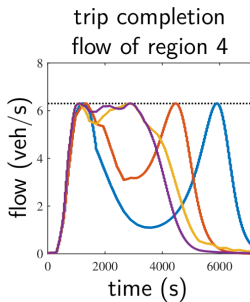
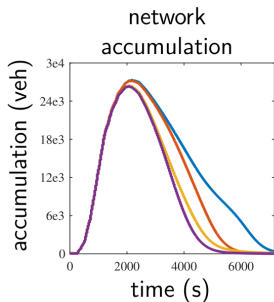
Actuation schemes

1. No control (NC)
 - $u_{ih}(t)$ fixed to u_{\max} ; $\theta_{ihj}(t)$ via route choice
2. Perimeter control MPC (PC)
 - Control input: $u_{ih}(\cdot)$; $\theta_{ihj}(t)$ via route choice
3. Route guidance MPC (RG)
 - Control input: $\theta_{ihj}(\cdot)$; $u_{ih}(t)$ fixed to u_{\max}
4. Perimeter control and route guidance MPC (PCRG)
 - Control input: $u_{ih}(\cdot)$ and $\theta_{ihj}(\cdot)$

Control structure/simulation setup

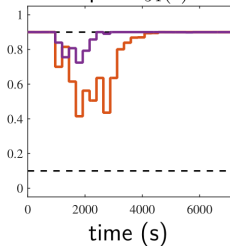


Congested scenario

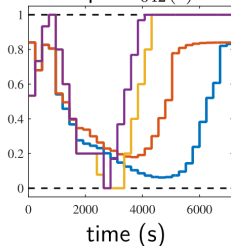


control scheme	imprv. over NC (%)	max. comp. time (s)
NC	0	—
PC	14	1.6
RG	27	6.1
PCRG	31	7.2

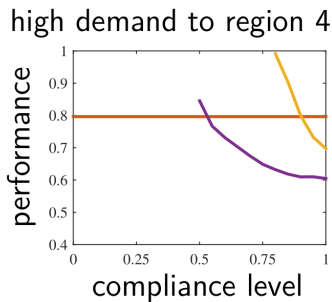
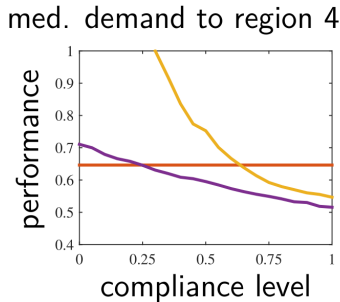
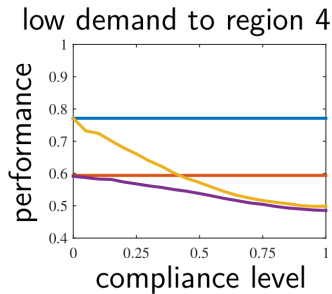
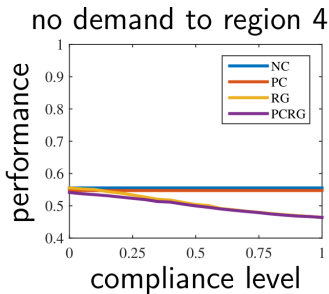
perimeter control input $u_{54}(t)$



route guidance input $\theta_{642}(t)$



Driver compliance analysis



Conclusion

Contribution:

- ▶ MPC with perimeter control and route guidance

Results:

- ▶ Improvement via route guidance
- ▶ Perimeter control to avoid severe congestion

Future work:

- ▶ How to realize $\theta_{ihj}(t)$? Assign drivers to paths

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