

Kentsel Karayolu Ulaşımı Sistemlerinin Optimizasyon-tabanlı Kontrolü, Durum Kestirimi ve Sistem Tanıması

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Kontrol Anabilim Dalı

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Kentsel mobilite yönetimi ihtiyacı

Los Angeles, 1941



Los Angeles, 2013



Mobilite yönetiminde çeşitli yaklaşımlar



bus
priority

signal
control



mobility
management

parking

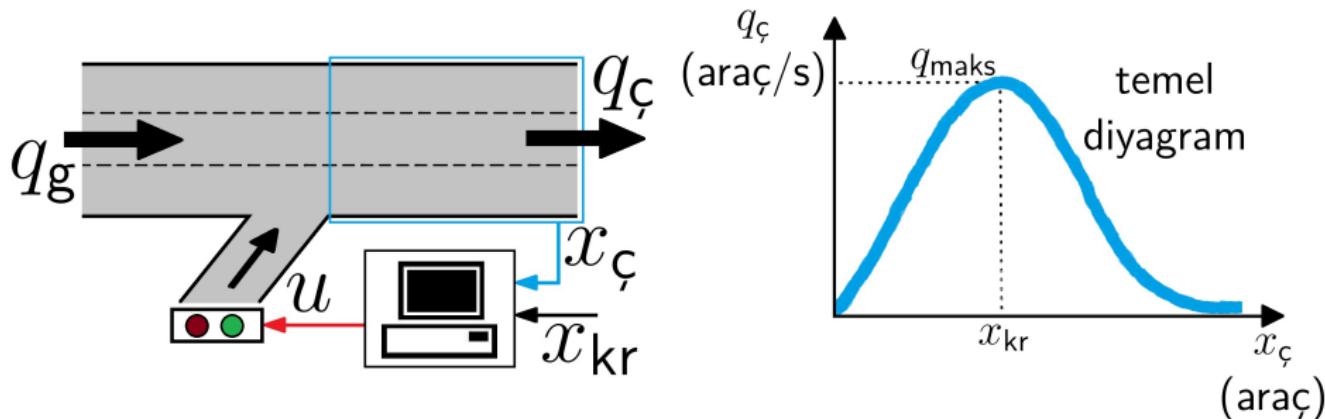


space
allocation



Karayolu trafiği akış kontrolüne giriş

Örnek: Otoyol rampası akış kontrolü¹



kontrol algoritması: $u(k) = u(k - 1) + P(x_{kr} - x_\zeta(k))$

$$k \in \{0, 1, 2, \dots\}$$

P : kontrolör parametresi

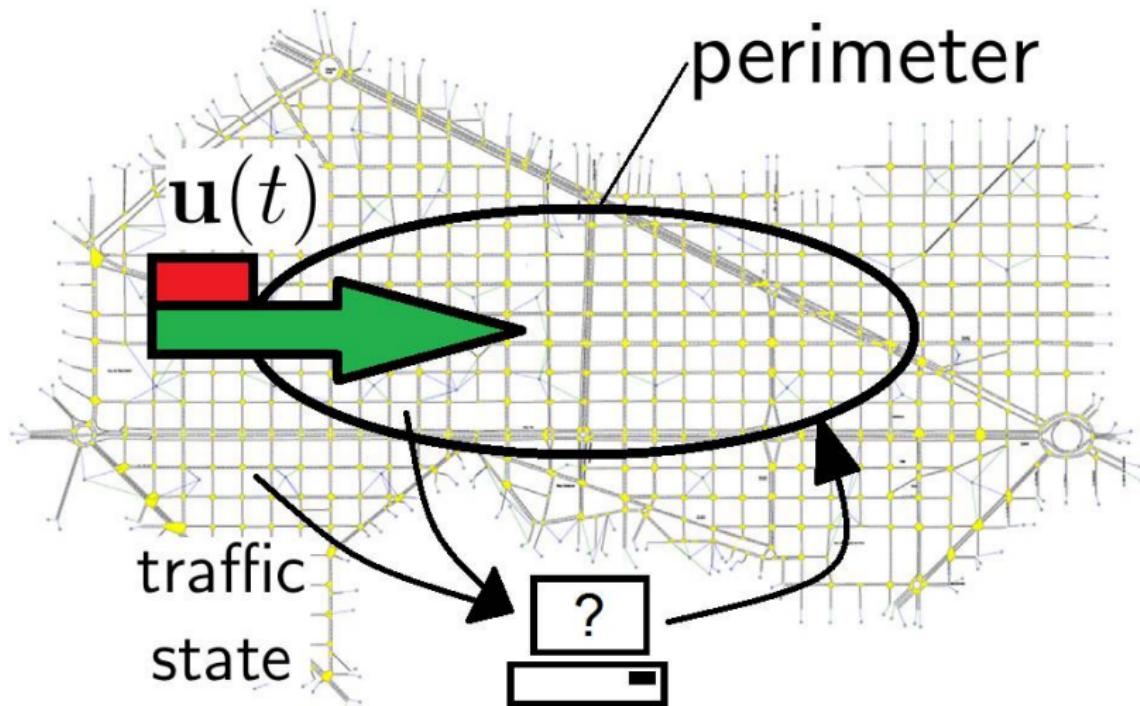
¹Markos Papageorgiou and Apostolos Kotsialos. *IEEE Transactions on Intelligent Transportation Systems* 3.4 (2002), pp. 271–281. URL:
<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1166514>.

Şehir ölçekli trafik sinyal kontrolü



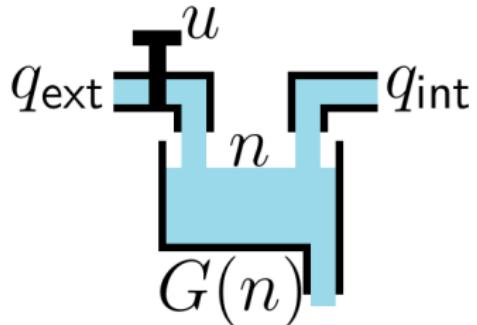
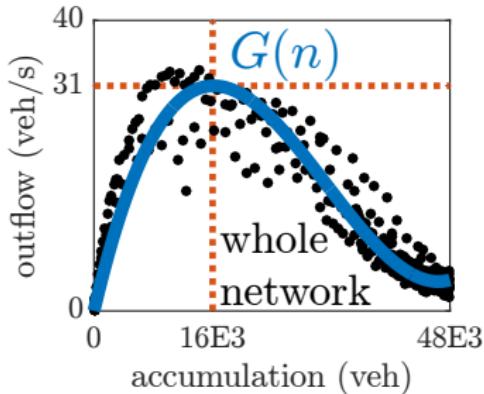
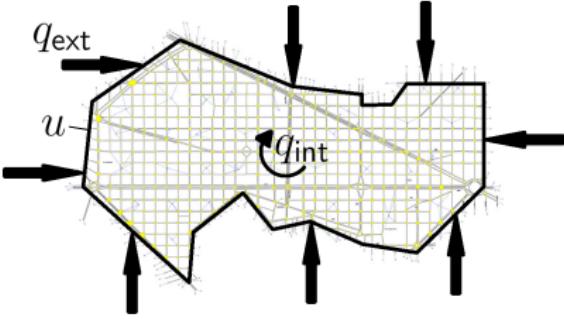
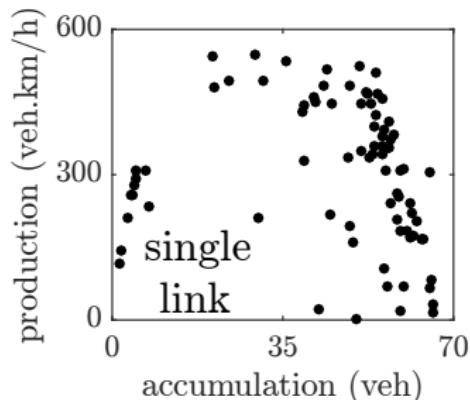
12 km², ~600 kavşak, ~1500 yol bağlantısı

Geri beslemeli perimetre kontrolü



örnek: $\mathbf{u}(t) = 0.8 \rightarrow$ trafik ışığı çevrimi %80 yeşil

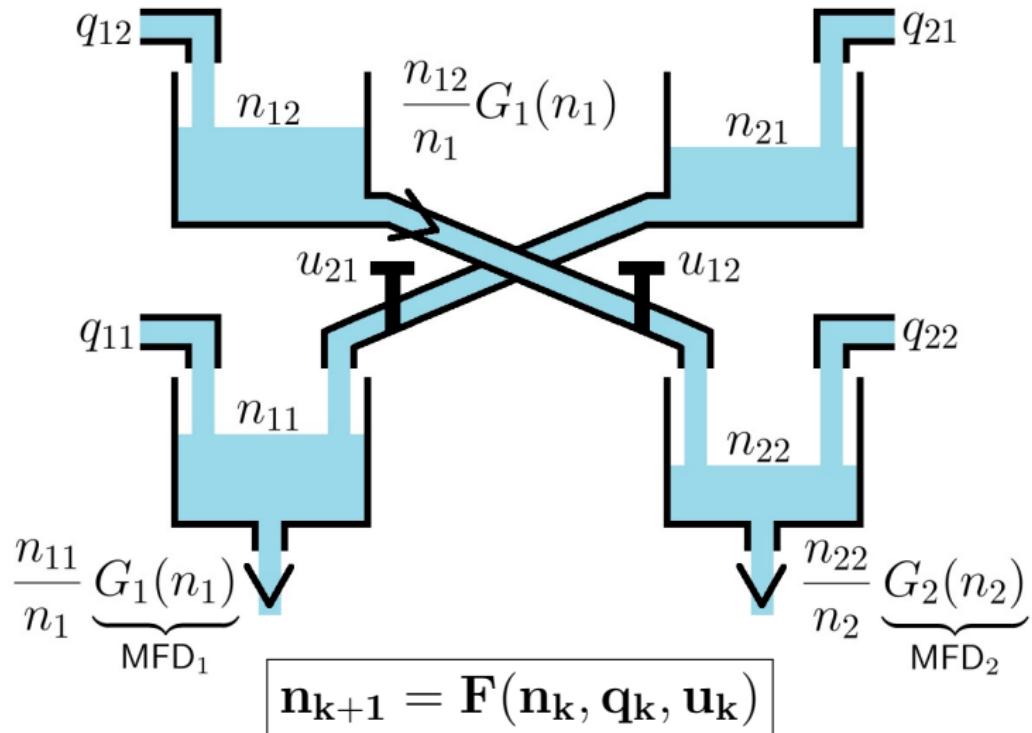
Makroskopik temel diyagram (MFD)^{2,3}



²J Godfrey. *Traffic Engineering & Control* 8.8 (1969).

³Nikolas Geroliminis and Carlos F Daganzo. *Transportation Research Part B: Methodological* 42.9 (2008), pp. 759–770.

İki bölgeli MFD sistemi dinamikleri⁴



⁴Nikolas Geroliminis, Jack Haddad, and Mohsen Ramezani. *IEEE Transactions on Intelligent Transportation Systems* 14.1 (2013), pp. 348–359.

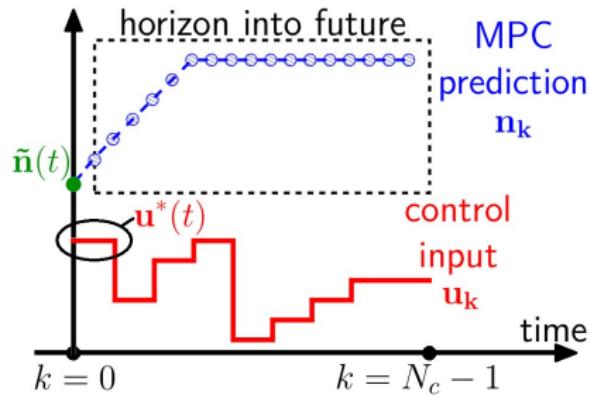
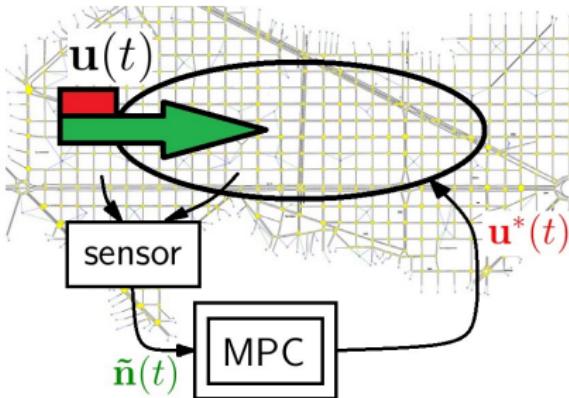
MFD-tabanlı kontrol literatürü

yayın	yöntem	test	bölge
Daganzo 2007	aç-kapa	makro	1
Keyvan-Ekbatani 2012	PI	mikro	1
Aboudolas 2013	PI	mikro	> 2
Geroliminis 2013	MPC	makro	2
Hajiahmadi 2013	MPC	makro	> 2
Hajiahmadi 2015	MPC	makro	2
Kouvelas 2017	PI	mikro	> 2
Zhou 2017	MPC	mikro	> 2
Ni 2019	MPC	mikro	> 2

inceLENmemiş doğrultular:

- durum kestirimi ve kontrol
- perimetre kontrolü ve rota yönlendirme

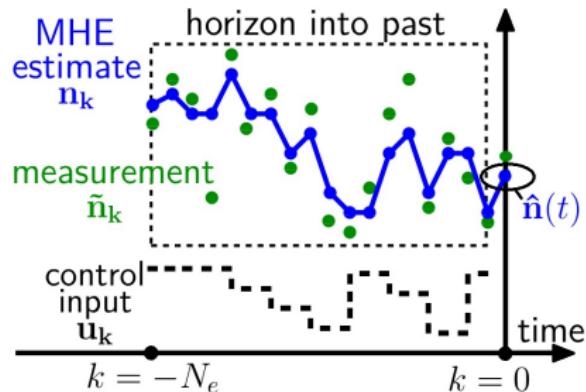
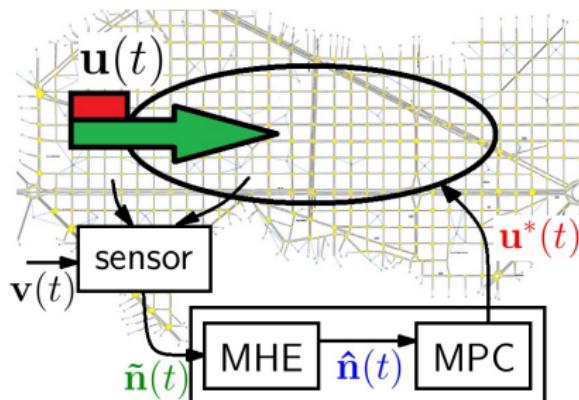
Model öngörülü kontrol (MPC)⁵



$$\begin{aligned} & \underset{\mathbf{u}_k}{\text{minimize}} \quad \sum_{k=0}^{N_c-1} \mathbf{1}^T \mathbf{n}_k \\ & \text{subject to} \quad \mathbf{n}_0 = \tilde{\mathbf{n}}(t), \quad \mathbf{u}_k \in \mathcal{U} \\ & \quad \mathbf{n}_{k+1} = \mathbf{F}(\mathbf{n}_k, \tilde{\mathbf{q}}(t), \mathbf{u}_k) \end{aligned}$$

⁵Nikolas Geroliminis, Jack Haddad, and Mohsen Ramezani. *IEEE Transactions on Intelligent Transportation Systems* 14.1 (2013), pp. 348–359.

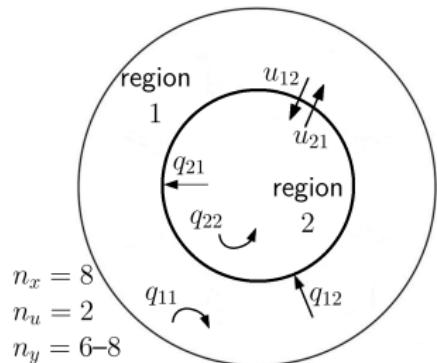
Hareketli ufkulu kestirim (MHE)⁶



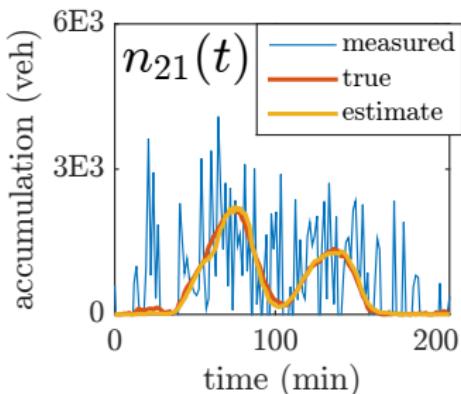
$$\begin{aligned} & \underset{\mathbf{w}_k}{\text{minimize}} \quad \sum_{k=-N_e}^{-1} \|\mathbf{w}_k\|_{\mathbf{Q}}^2 + \sum_{k=-N_e}^0 \|\mathbf{v}_k\|_{\mathbf{R}}^2 \\ & \text{subject to} \quad \mathbf{n}_{k+1} = \mathbf{F}(\mathbf{n}_k, \tilde{\mathbf{q}}(t), \mathbf{u}_k) + \mathbf{w}_k \\ & \quad \tilde{\mathbf{n}}_k = \mathbf{h}(\mathbf{x}_k) + \mathbf{v}_k \end{aligned}$$

⁶Isik Ilber Sirmatel and Nikolas Geroliminis. *IEEE Transactions on Intelligent Transportation Systems* (2019).

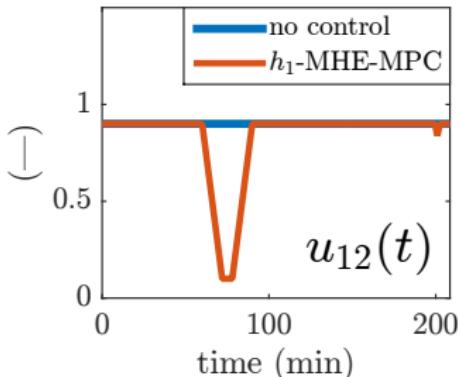
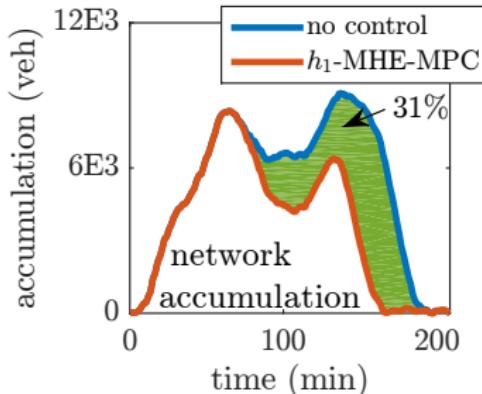
Makroskopik benzetim sonuçları



kestirim başarımı



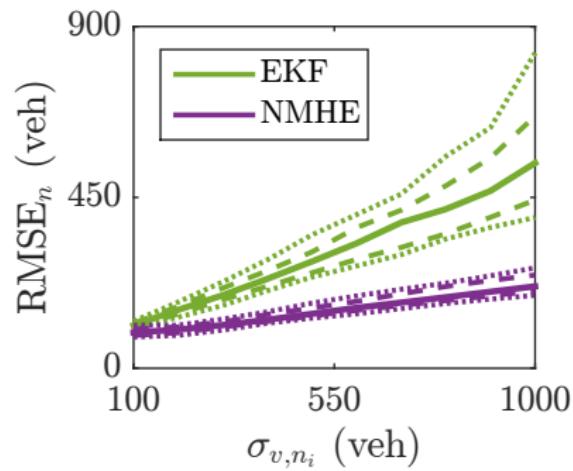
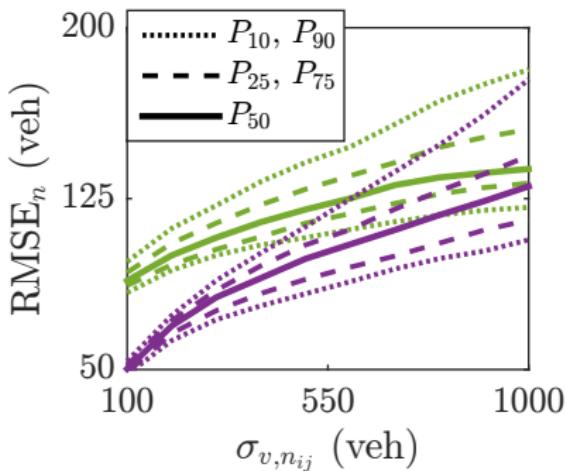
kontrol başarımı



Makroskopik benzetim sonuçları

h₁: n_{ij} and q_{ij} ($\mathbf{h}(\mathbf{x})=\mathbf{x}$)

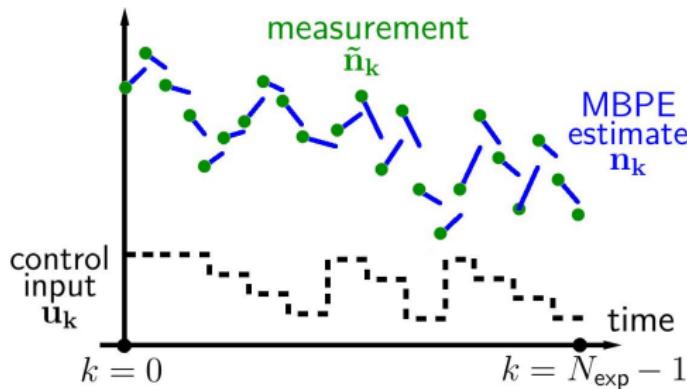
h₄: n_i , M_{ij} , and q_i



x-ekseni: gürültünün standart sapması

y-ekseni: kestirim hatasının RMS değeri

Model-tabanlı parametre kestirimi⁷



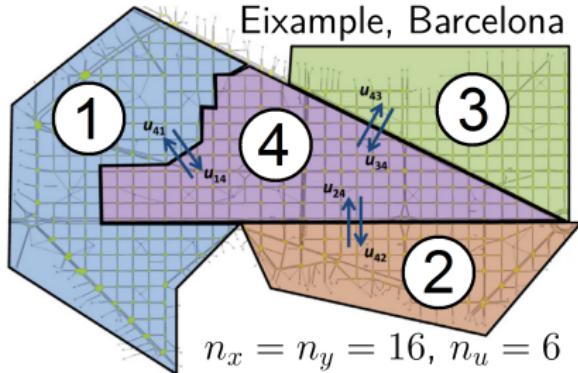
$$\underset{\mathbf{p}, \mathbf{w}_k, \mathbf{z}_k}{\text{minimize}} \quad \sum_1^{N_{\text{exp}}} \|\mathbf{w}_k\|_{\mathbf{Q}}^2 + \|\mathbf{v}_k\|_{\mathbf{R}_n}^2 + \|\mathbf{z}_k\|_{\mathbf{R}_q}^2$$

$$\text{subject to} \quad \mathbf{n}_{k+1} = \mathbf{F}_{\mathbf{p}}(\tilde{\mathbf{n}}_k, \tilde{\mathbf{q}}_k, \mathbf{u}_k) + \mathbf{w}_k$$

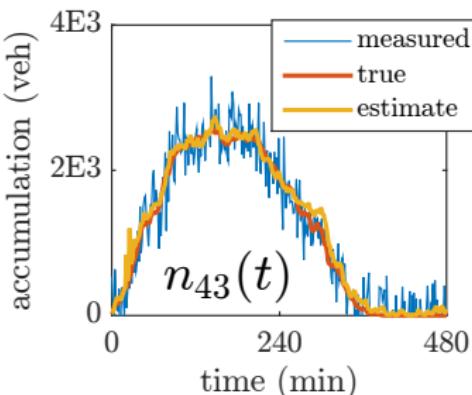
$$\tilde{\mathbf{n}}_k = \mathbf{n}_k + \mathbf{v}_k, \quad \tilde{\mathbf{q}}_k = \mathbf{q}_k + \mathbf{z}_k$$

⁷Isik Ilber Sirmatel and Nikolas Geroliminis. 2020 European Control Conference (ECC). IEEE. 2020, pp. 408–413.

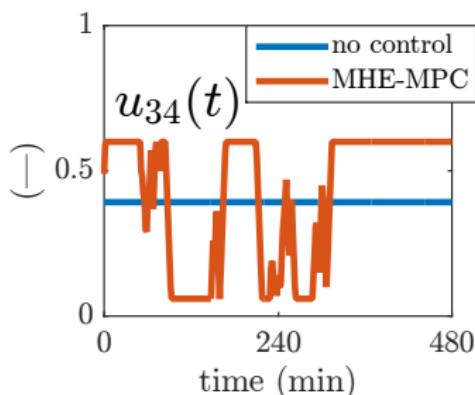
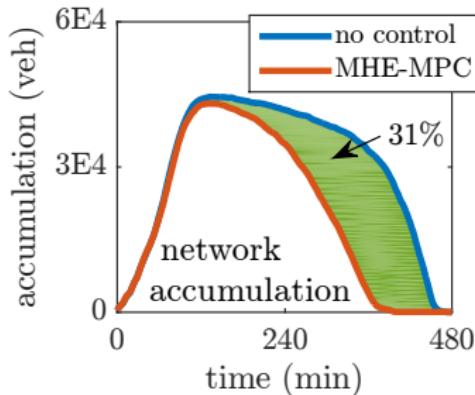
Mikroskopik benzetim sonuçları



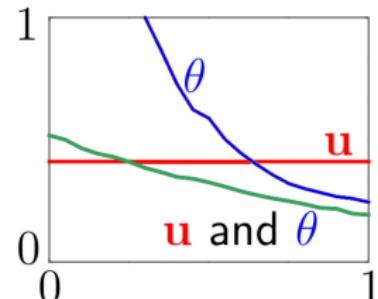
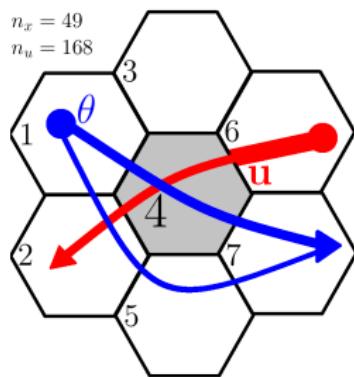
kestirim başarımı



kontrol başarımı



Perimetre kontrolü ve rota yönlendirme⁸



x-ekseni: sürücü uyumu
y-ekseni: harcanan zaman

$$\begin{aligned} & \underset{\mathbf{u}_k, \theta_k}{\text{minimize}} \quad \sum_{k=0}^{N_c-1} \mathbf{1}^T \mathbf{n}_k \\ & \text{subject to} \quad \mathbf{n}_0 = \tilde{\mathbf{n}}(t), \quad \mathbf{u}_k \in \mathcal{U}, \quad \theta_k \in \Theta \\ & \quad \mathbf{n}_{k+1} = \mathbf{F}_\theta(\mathbf{n}_k, \tilde{\mathbf{q}}(t), \mathbf{u}_k, \theta_k) \end{aligned}$$

⁸Isik Ilber Sirmatel and Nikolas Geroliminis. *IEEE Transactions on Intelligent Transportation Systems* 19.4 (2018), pp. 1112–1121.

Sonuç

katkılar:

- ▶ MFD-tabanlı MPC+MHE ve MBPE
- ▶ perimetre kontrolü ve rota yönlendirme

sonuçlar:

- ▶ MPC+MHE → gürültüde başarıım
- ▶ rota yönlendirme → düşük uyumda başarıım

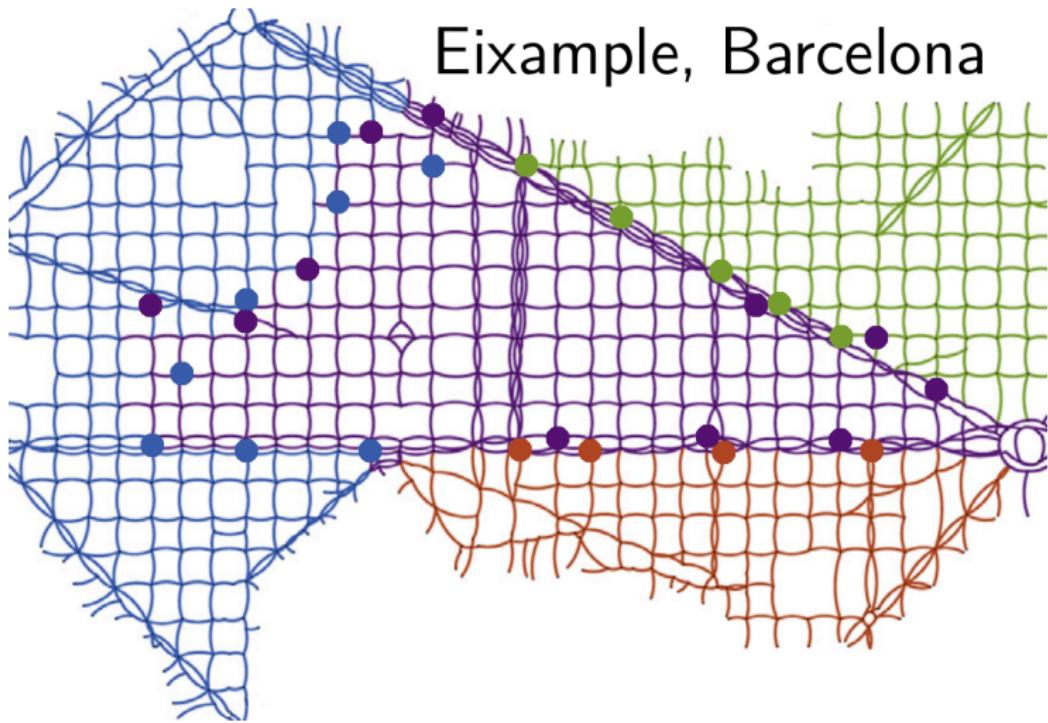
devam eden araştırmalar:

- ▶ model/sistem ilişkisi, dayanıklılık

gelecekteki araştırmalar:

- ▶ konvansiyonel/otonom karma trafikte kontrol
- ▶ hiyerarşik ve dağıtık kontrol

Soru-cevap



12 km², ~600 kavşak, ~1500 yol bağlantısı