Integrated Traffic Network Control
---A mixed network with freeway and urban road

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Shanghai, 23 Jun, 2014
Outline

➤ Introduction
➤ Methodology
➤ Case studies
➤ Conclusions and future research
Introduction

Disadvantages:
- Off-line control: Ineffective with disturbances, such as emergency.
- Decentralized control: Unsuitable for heterogeneously loaded traffic network.
- Limited-sized: Can’t be used to real life networks, or just be used as local control, which may shift the congestion problem to other part of the network.
Introduction

Basic framework:

Control measures:
Intersection signal.
Variable message sign.
Ramp metering installation
### Methodology

**Cell-based store and forward model:**

\[
x_k(n+1) = x_k(n) + a_k(n) + \sum_{\{j:d_j=k\}} u_j(n) f_j - \sum_{\{j:s_j=k\}} u_j(n) f_j
\]

\[
m_k^d(n+1) = \sum_{\{j:d_j=k\}} \sum_{\{l:s_j=l\}} u_j(n) f_j m_l^d(n) + m_k^d x_k(n) + \sum_{\{j:s_j=k\}} \sum_{\{l:d_j=l\}} u_j(n) f_j m_l^d(n)
\]

\[
u_j = \min(x_{s_j} + i_{s_j}, c_{d_j} - x_{d_j} - o_{d_j}, f_j) / f_j, s_j \notin D
\]

\[
u_j = x_k(n)m_k^d(n) / f_j, s_j \in D
\]

\[0 \leq x_k(n) \leq c_k, \forall k, n\]
Methodology

Linear quadratic model predictive control:

$$\min_{i=n}^{n+N_1N_2-1} \sum \left[ X(i+1)'QX(i+1) + RU(i) \right]$$

s.t.

$$B = \begin{bmatrix} Ds & 0 & \cdots & 0 \\ Dsd & Ds & \ddots & \vdots \\ \vdots & \ddots & \ddots & Dsd \\ Dsd & \cdots & Dsd & Ds \end{bmatrix}$$

$$H = \begin{bmatrix} Dds & 0 & \cdots & 0 \\ Dds & Dds & \ddots & \vdots \\ \vdots & \ddots & \ddots & Dds \\ Dds & \cdots & Dds & Dds \end{bmatrix}$$

$$P = \begin{bmatrix} pj_1 \\ pj_2 \\ \vdots \\ pj_{N_1N_2} \end{bmatrix}$$

$$D = \begin{bmatrix} dj_1 \\ dj_2 \\ \vdots \\ dj_{N_1N_2} \end{bmatrix}$$
Methodology

Driver’s route choice modelling:

\[ \beta^m = \frac{\exp(-\sigma \times t^m)}{\exp(-\sigma \times t^{m1}) + \exp(-\sigma \times t^{m2})} \]

\( t \) is the route travel time. \( \sigma \) describes how drivers react on a travel time difference between two alternatives. The value of it is based on reasonable experimental results.
Case studies

Case 1: Network setup

Conceptual network of the case study: There are two origins and one destination in this network.

The network contains five heterogeneous links:
Black line: freeway;
red line: disturbance areas;
light blue line: major arterial road
dark blue line: urban road
green line: ramps.

There are two RMSs and one DRGS in this network control system.
Case studies

Case 1: Model and control parameters

Parameters for freeway, arterial road, urban road and ramp:
Free flow speed: 120km/h, 90km/h, 60km/h and 30km/h.
Cell length: 1 km, 750 m, 500 m and 250 m.
Flow rate: 50, 30, 20, 10 (veh/time step).
Maximum queue length: 405, 200, 135, 35 (veh/cell).
Simulation step: 30s.
Prediction horizon: 5 min.
Case studies

Case 1: Scenarios

1. User equilibrium of the network without disturbance.
2. System optimal of the network without disturbance.
4. No guidance of network with disturbance.
5. Integrated control of network with disturbance.

Demand profile:
Case studies

Case 1: Results

[Graphs and diagrams related to the case study results]
Case studies

Case 1: Results

when control interval is 30s, the whole simulation time is 11.88 seconds; 60s corresponds to 11.81 seconds; 90s corresponds to 11.67 seconds.
Case studies

Case 2: Network setup

The grey nodes represent the metered on-ramps and the black nodes the intersections with signal control.
Control measure: routing.
Case studies

Case 2: Results

1. System optimal scenario
2. UE routing scenario
3. No routing scenario

The intersection signal of scenario 2 and 3 are generated from MPC controller, but their route choice behaviour are different. Scenario 2 use UE routing, the compliance rate is 1, while scenario 3 has no routing control.
Case studies

Case 3: Network setup

The grey nodes represent the metered on-ramps and the black nodes the intersections with signal control.

Control measure: intersection signal.
Case studies

Case 3: Results

1. System optimal case
2. MPC control case
3. Fix-time control case

Total delay: 74.5h
Total delay: 150.9h
Total delay: 168.0h

Both scenario 2 and 3 use UE routing. Their intersection control are different. The intersection signal of scenario 2 was generated from MPC controller, while intersection signal of scenario 3 used fix time control plan.
Conclusions

- Try to combine the variational route choice behaviour into the predicting model and the controller.
- Try to integrate ramp metering installation into the controller.
  - Try to expand the urban network size.
Future research

- Try to combine the variational route choice behaviour into the predicting model and the controller.
- Try to integrate ramp metering installation into the controller.
  - Try to expand the urban network size.
Thanks for your attention!