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Adaptive coordinated traffic signal control: a rolling horizon optimization scheme

Dr. Lubing LI

Dr. Hong K. LO

Dr. Wei HUANG

1. Department of Civil and Environmental Engineering

The Hong Kong University of Science and Technology

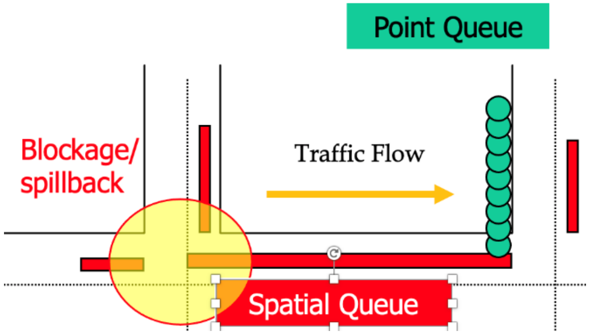
2. School of Intelligent Systems Engineering

Sun Yat-sen University, Guangdong, China

Three characteristics of traffic flow

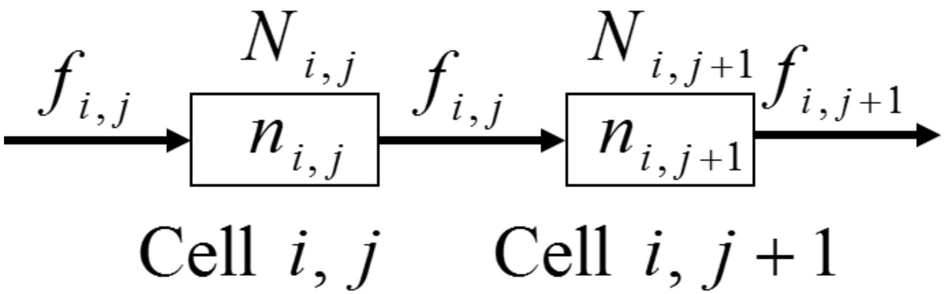
To properly develop a traffic signal control platform, it is critical to incorporate three fundamental characteristics of traffic flow

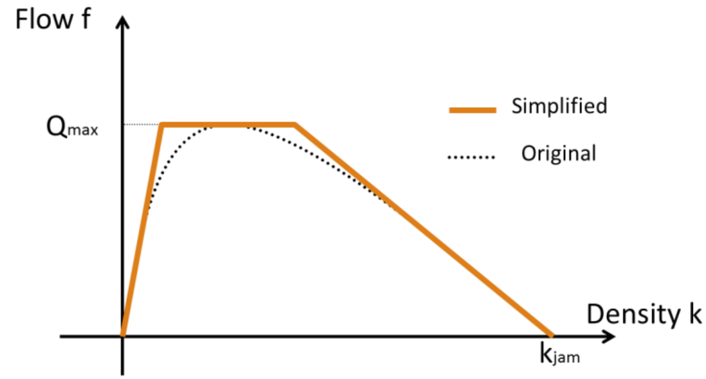
- Dynamic : traffic dynamics vary over time
- Spatial : traffic has physical dimensions, spills backward, and blocks junctions
- Stochastic : traffic arrivals are random and cannot be predicted perfectly.



Cell Transmission Model (CTM)

- ❑ Cell-Transmission Model (Daganzo, 1994, 1995) to model traffic dynamics: a convergent approximation to the LWR model (Lo et al., 1999; Lo 2001)





- ❑ A sort of finite difference approach for efficient solution
  - ➢ Cell inflow equation

$$f_{i,j}(t) = \min\left\{Q_{i,j}(t), n_{i,j}(t), \frac{W}{V}\left[N_{i,j+1}(t) - n_{i,j+1}(t)\right]\right\}$$

Inflow Capacity — Flow waiting — Available space

  - ➢ Conservation condition for normal cell:

$$n_{i,j+1}(t+1) = n_{i,j+1}(t) + f_{i,j}(t) - f_{i,j+1}(t)$$

Two-stage stochastic program formulation

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(Stage-1)

$$\min_{C,\mathbf{G},\mathbf{O}_{ini}} E_{\Omega}[D(C,\mathbf{G},\mathbf{O}_{ini})] = \sum_{k\in\Omega} P_k(\hat{v}_k)\cdot D_k(C,\mathbf{G},\mathbf{O}_{ini},\hat{v}_k)$$

s.t.

$$G_1(C,\mathbf{G},\mathbf{O}_{ini}) \geq 0$$

(Stage-2)

where:

$$\min_{\mathbf{O},\Delta\mathbf{G}} D_k(\mathbf{O},\Delta\mathbf{G}\,|\,\hat{v}_k) = \sum_t \sum_l d_l^k(t)$$

s.t.

$$G_2(\mathbf{O},\Delta\mathbf{G}) \geq 0$$

Stage-1
Minimize delay with respect to {C, G, O_{ini}}

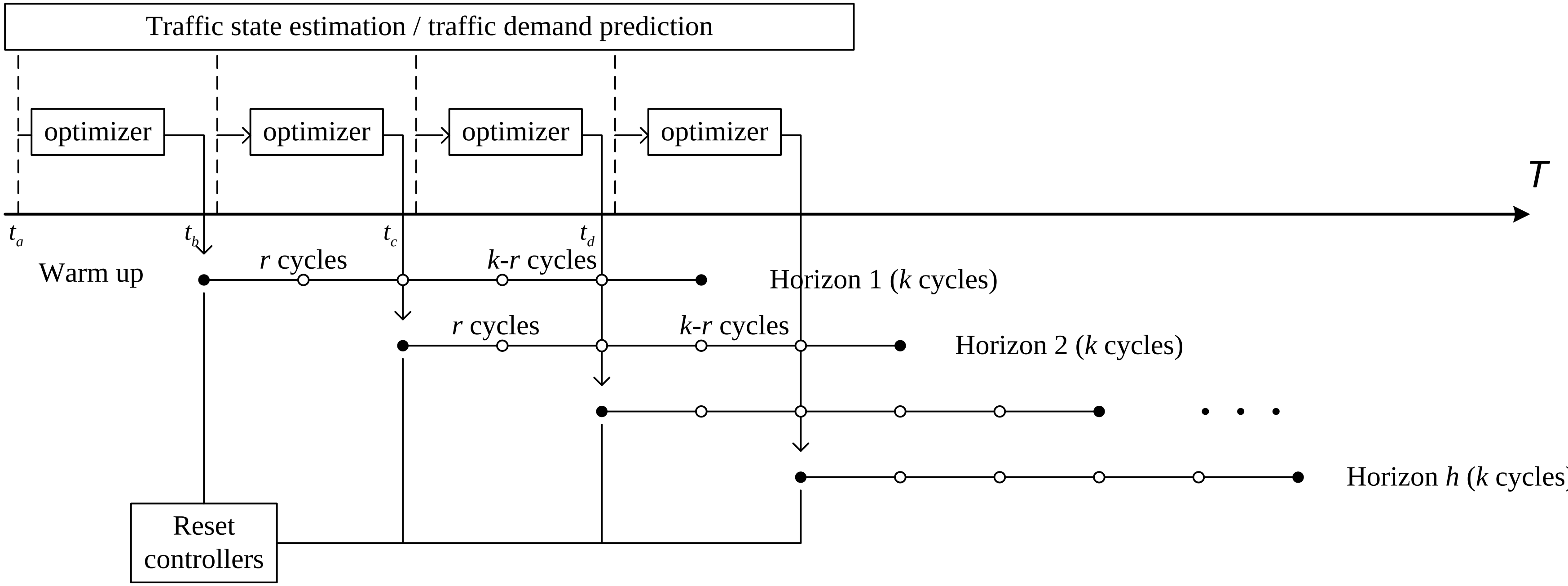
The expected cost of the optimal recourse decisions is then added to the objective function.

Upon realization of the uncertain demand, recourse decisions are made in the second stage to adapt to the random demand.

Stage-2
Minimize delay with respect to O, ΔG

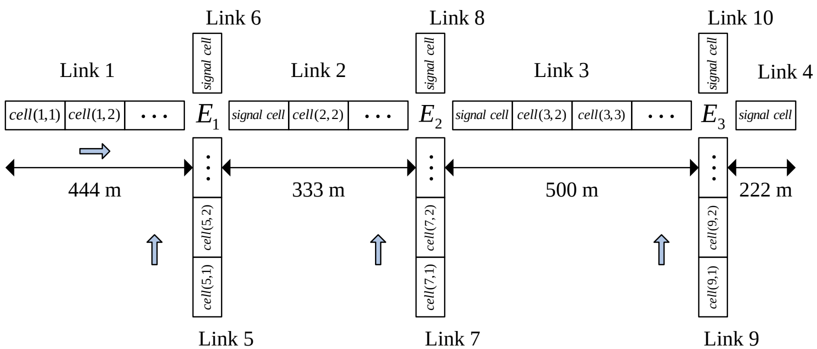
The optimal policies include the stage-1 policy (base timing plan) and a collection of recourse decisions of stage-2 which are actions in response to random demand scenarios (actual offsets and green extensions).

Two-stage scheme implementation

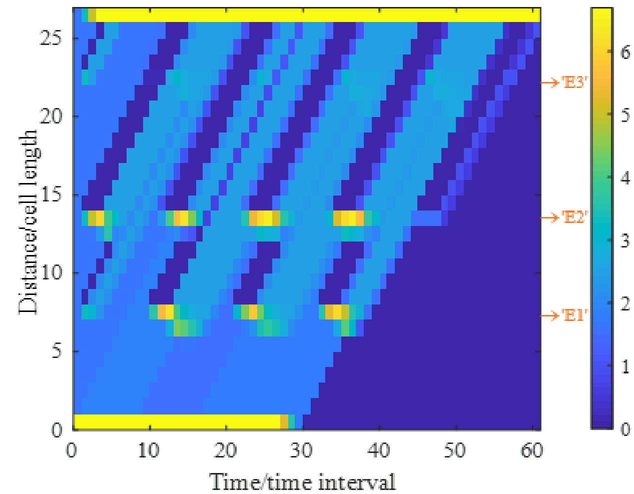


- One horizon consists of two parts: the first *r* cycles of the horizon (the ‘head’) and the rest (*k*-*r*) cycles of the horizon (the ‘tail’).
- The adaptive signal control variables are optimized for *k* consecutive cycles in the horizon *h* but with only the signal strategies of the ‘head’ *r* cycles implemented and the signal strategies of the ‘tail’ (*k*-*r*) cycles discarded.
- After the implementation of the signal strategies for the ‘head’ cycles, the horizon is then rolled (shifted) *r* cycles ahead and the adaptive strategies for the next horizon are re-optimized with the newly updated traffic arrival and queueing information.

Case study



- Free-flow speed: 40 km/h;
- Backward shock wave speed: 20 km/h;
- Jam density: 120 vehicles/km (16.67 vehicles/cell);
- Cell length: 55.6 m.
- Saturation flow: 1600 vehicles/hour;
- Minimum green: 15 seconds;
- Maximum cycle: 120 seconds;
- Inter green time: 4 seconds.



- ❑ We link optimization model to VISSIM and build up "**software-in-the-loop system**" to assess the performance of the adaptive signal plans.
- ❑ Adaptive policies are optimized with the real-time queueing and vehicle arrival information collected in VISSIM and deployed to intersections at the start of each horizon.

Table 1. Delay (sec/veh) performance

Sim. runs	1	2	3	4	5	6	7	8	9	10	OA average delay
New meth. Del.	25.39	24.43	24.10	25.63	23.60	23.71	26.30	25.67	22.59	21.73	24.31
Classical meth. Del.	36.56	34.59	34.56	33.58	34.39	34.12	34.75	34.97	33.56	32.78	34.39
Delay reduction	**30.6%**	**29.4%**	**30.3%**	**23.7%**	**31.4%**	**30.5%**	**24.3%**	**26.6%**	**32.7%**	**33.7%**	**29.3%**

Thank you for your attention !