Hierarchical and Distributed Urban Traffic Control

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Outline

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   - Traffic Control
2. Hierarchical Urban Traffic Control
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   - Implementation
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   - Traffic Agents
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Urban Traffic Control

Basic concepts

Global aim: **Reduce the travel time.**

Means

- green waves
- signal plan synchronisation

Signalised intersection control

- fixed
- vehicle-actuated, public transport preference
- coordinated

Measurements (inductive loops, video) ⇒ **controller** ⇒ **traffic signals**.

Traffic Control
Measurements

Detectors provide

- *intensity* – number of vehicles in a period
- *occupancy* – percentage of the period when the detector was occupied
- speed, traffic flow density, . . .

Control variable

- *green length* – nominal length of the green signal
- variable message signs, . . .
- disturbances: vehicle actuated signals, PT preference, signal plan transitions

Green signal → signal group → signal plan.

Hierarchical Urban Traffic Control

Why?

Higher traffic demands

- conflicting traffic flows
- need for signal coordination
- synchronisation

Need to keep the local intersection controller
But local preferences have to be bound

Result

- limited local freedom of controller
- "supervisory" controller optimising the global state

Two-level hierarchy.

Macroscopic Model of a Microregion

In development at AS ÚTIA

- Basic assumption: delay $\sim$ queue length
- Internal states: $\theta_t = \mathbf{A}\theta_{t-1} + \mathbf{B}u_{t-1} + \mathbf{F} + e_t$
- Output: $y_{[\mathrm{out}],t} = \mathbf{C}x_t + \mathbf{D} + \epsilon_t$
- e_t, ϵ_t is noise (accounts for unobservable data)
- u_t are traffic control variables (green lengths)
- θ_t holds queue lengths ξ_t, input and output intensities
- $y_{[\mathrm{out}],t}$ are output intensity predictions

Kalman DD1 (non-detected data and unknown parameters) followed by optimisation using standard linear programming.

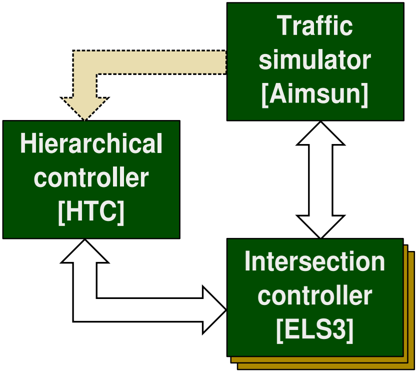
Platform

MATLAB:

- generally accepted tool
- rapid prototyping
- code recycling
- not suitable for large projects
- tricky internal bugs

Interface to

- TSS/Aimsun (microscopic simulator – model verification)
- ELS3 prototype (real intersection controller)



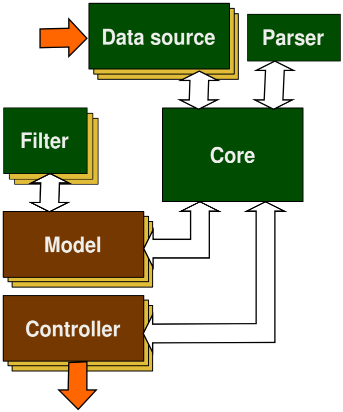
Architecture of the HTC

Modular structure

- core (read, write, test reports)
- model (two versions)
- controller (linprog version)

Slight changes from the last year

- separate network description parser
- filter plugins
- datasources



Functional closed loop control of TSS/Aimsun transport simulator.

Issues

Varying cycle period × Fixed measurement period

Non-linear parameter estimation

We want to control a system that is:

Uncertain: we do not know (or do not observe):
(i) where the drivers want to go,
(ii) obstacles on the streets,
(iii) breakage of measuring devices.

Distributed in

space: many intersections,

& time: quality of control can be evaluated only in long-term.

Distributed Urban Traffic Control

Initial experiments with totally distributed control:

- Fuzzy
- Game theory
- **Bayesian decision-making**

Need to

- create locally optimal signa plans
- coordinate them with neghbours

Hidden centralisation — communication lines, space requirements, supervisors, and so on.

Bayesian UTC Agents

A very short explanation

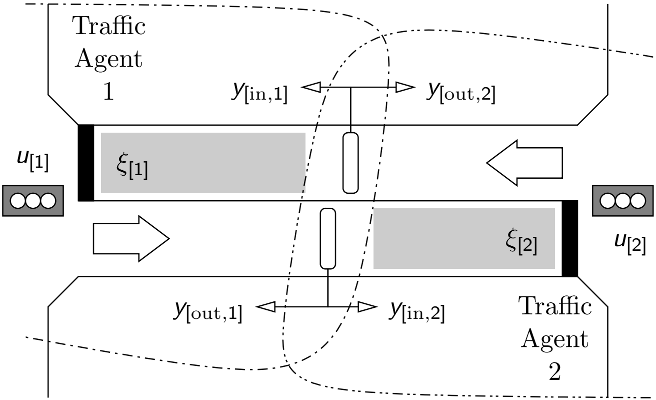
Single Bayesian decision-maker $\Rightarrow$ Bayesian Agent by adding negotiation capabilities

Experiment in urban traffic control (Šmídl and Přikryl, 2006):

- Agent is an intersection controller
- Internal model yielding queue lengths
- Global negotiation with the aim to keep queues at minimum

Bayesian UTC Agents

An example



Bayesian UTC Implementation

Probabilistic model

Based on the deterministic one presented earlier:

$$
\begin{aligned}
f(\Theta_t|\Theta_{t-1}, u_{t-1}, y_{[\mathrm{in}],t-1}) &= t\mathcal{N}\left(A_t\Theta_{t-1} + B_t u_{t-1}, Q_t, \langle 0, \Theta_{\max}\rangle\right), \\
f(y_{[\mathrm{out}],t}|\Theta_t, u_t, y_{[\mathrm{in}],t-1}) &= t\mathcal{N}\left(C_t\Theta_t + D_t u_t, R_t, \langle 0, y_{\max}\rangle\right).
\end{aligned}
$$

- $t\mathcal{N}(\mu, V, \langle x_{\min}, x_{\max}\rangle)$ is the truncated Gaussian distribution
- u_t are traffic control variables (green lengths)
- θ_t holds queue lengths ξ_t, input and output intensities
- $y_{[\mathrm{in}],t}$ are incoming measurements
- $y_{[\mathrm{out}],t}$ are outgoing measurement predictions

Bayesian UTC Implementation
Ideals

Every agent formulates its aims in the form of “ideal pdf”.

Ideal on queue and outputs:

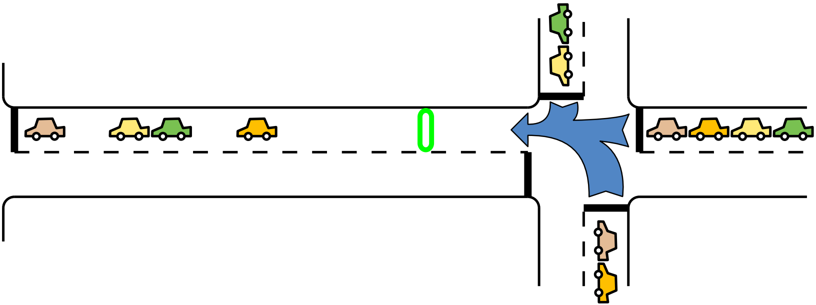
$$\begin{aligned} {}^{I}f(\xi_t) &= t\mathcal{N}\left(0, V_\xi, \langle 0, \xi_{\max}\rangle\right), \\ {}^{I}f(I_{[\mathrm{out}],t}|\xi_t) &= t\mathcal{N}\left(I_{[\mathrm{out}],\max}, V_{I[\mathrm{out}]}, \left\langle 0, I_{[\mathrm{out}],\max}\right\rangle\right) \end{aligned}$$

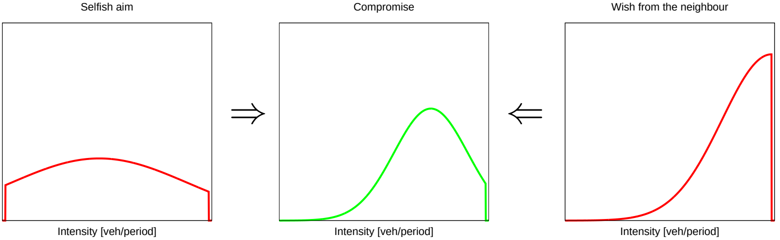
Ideal on inputs:

$${}^{I}f(I_{[\mathrm{in}],t}|\xi_t) = t\mathcal{N}\left(I_{\mathrm{w}}\left(\xi_t\right), V_{I[\mathrm{in}]}, \left\langle 0, I_{[\mathrm{in}],\max}\right\rangle\right)$$

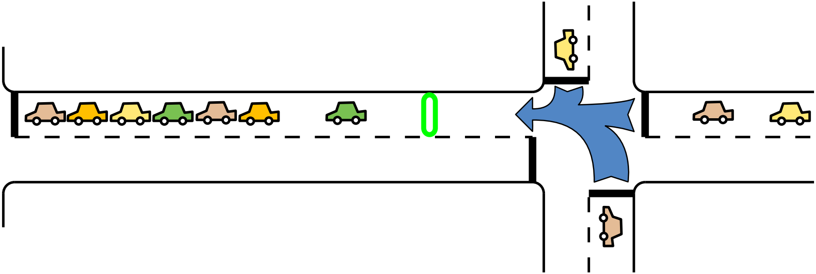
Many other ideal pdf formulations possible ...

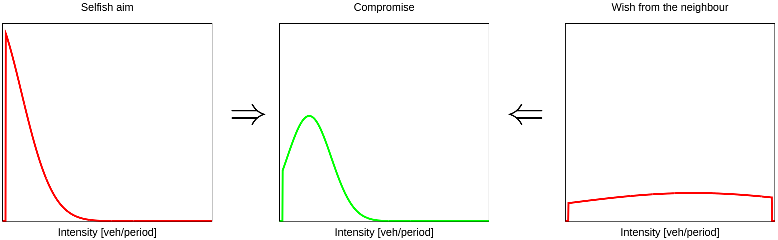
Merging of probabilities





Merging of probabilities





Summary

HTC status

- linearised state model
- filtering for parameter and state estimation
- closed loop experiments with TSS/Aimsun
- interface for ELS3

Traffic agents experiments

- first attempt in distributed Bayesian decision-making
- imperfect pdfs (truncated Gaussian pdfs)
- questionable ideals