Simulation Results of Urban Traffic Control Algorithm

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Outline

1. Basic Concepts and Quantities
   - Traffic Control
2. HRD (Urban Traffic Control System from UTIA)
3. Testing
4. Summary

Introduction
Quantities

Inductive loops

Intensity:

- number of vehicles passing a detector over some period
- typically [veh/hr] or [veh/90s]

Occupancy:

- percentage of the detection interval when detector occupied
- loop sampling rate 10Hz

Velocity: can be determined from the shape of the signal

Turning rate: percentage of the cars leaving particular outgoing arm at an intersection

Introduction
Quantities

Saturation flow S:

- maximum flow of an arm
- given by construction parameters
- typical value around 1900 veh/hr

Cycle time T_c:

- ratio of particular signals in a signal plan
- varies from 60 sec (night) to 120 sec

Green split:

- ratio of particular signals in a signal plan

Traffic control
Basic mechanisms

Signal lights

- fixed signal plans (TASS)
- traffic-responsive local control
- traffic-responsive area control (UTOPIA, SCOOT, MOTION, ...)

Variable Message Signs (VMS)

- change of speed limits
- informative messages (time of travel, street closures)

Traffic control
Signal light settings

Gating – keep the drivers out of the controlled area.

Green waves – signal offset optimisation that minimises number of stops.

Split optimisation – traffic-responsive signal group length and ordering.

Cycle length optimisation – longer T_c in case of higher traffic intensity.

Outline

HRD
General

Initial assumptions:

- long arterials
- enough strategic detectors
- simple macroscopic approach

Goal: to have a simple adaptive traffic regulator that would

- optimise splits
- optimise cycle lengths
- not have too many knobs
- not be a black box from user's point of view

HRD

Macro-level model – state equations

Two sets of equations (i-th lane, k-th time step):

Queue development

$$\xi_{i,k+1} = \delta_{i,k}\xi_{i,k} + (\delta_{i,k}S_i + (1-\delta_{i,k})I_{\text{in},i,k})z_{i,k} + I_{\text{in},i,k}$$

$\xi \ldots$ queue length, $\delta \ldots$ saturation flag, $\delta \in \{0,1\}$, $z \ldots$ relative green length

Occupancy correction

$$O_{i,k+1} = \kappa\xi_{i,k} + \beta O_{i,k} + \lambda$$

κ, β, λ have to be determined a priori or estimated

Note: queue development equation covers two disjunct scenarios (saturation, free flow).

HRD

Macro-level model – output equations

Again two sets:

Output intensity

$$I_{\text{out},i,k} = \sum_{j \in \mathbf{A}_i} \left[\delta_{j,k} \alpha_{ji} \xi_{j,k} + (\delta_{j,k} S_j + (1 - \delta_{j,k}) I_{\text{in},j,k}) z_{j,k} + I_{\text{in},j,k} \right]$$

Occupancy

$$O_{i,k} = O_{i,k}$$

Note: occupancy measurements do not have direct influence on queue length when filtering.

HRD
Filtering

We cannot measure everywhere, and detectors tend to fail.

Kalman filter:

- can be used with offline κ, β, λ estimates
- applicable to isolated intersections

DD1 filter:

- can be used to estimate κ, β, λ
- very robust if covariances set properly
- bad performance with improper covariances

General challenge: how to set initial covariances.

HRD
Control criterion

General idea: **delay** $\approx$ **queue length**.

Realisation: **linear programming**

1. predict intensities for several control steps in advance (3-5)
2. set up a system of queue predictors
3. set up LP conditions (limits for green changes, queue lenghts)
4. optimise for approximately same delays
5. apply and look what happens

Evaluation Criteria for UTC Strategies

Measures of UTC efficiency

Our measure of queue length is related to

travel time . . . total time needed to travel through the network

delay time . . . time difference induced by queueing

number of stops . . . imposed by the current traffic situation

Simulated data from AIMSUN include periodical and cumulative statistics.

Evaluation Criteria for UTC Strategies

Comparing UTC efficiency

Literature: Compare with fixed-time control

- fixed-time is the de-facto standard
- implementing different global UTC strategies is time-consuming and administratively demanding
- any traffic-responsive strategy shall be able to beat fixed-time control

Czech speciality: Compare with local traffic-responsive dynamics

- local traffic-responsive control is popular in urban areas
- differences between global traffic-responsive strategies and local dynamics are smaller
- the comparison is fairer

Platform and Architecture
Matlab and Pseudo-OOP

Mentioned already numerous times

Basic requirements:

- MATLAB (reusable components, bindings to Mixtools 3000)
- Interchangeable code components

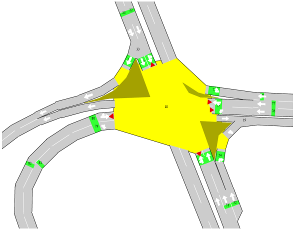
Solution:

- Pseudo OOP in Matlab using path shadowing
- Interchangeable models
- Interchangeable filters (Kalman, DD1)
- Low-level interface in ANSI C

Implementation issues
Simulator

"Features" of the underlying simulator:

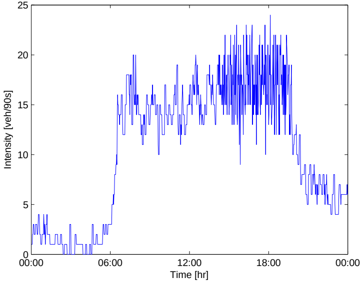
- Aimsun does not distinguish vehicles on separate lanes
- Simulation code permits nonsense parameter settings

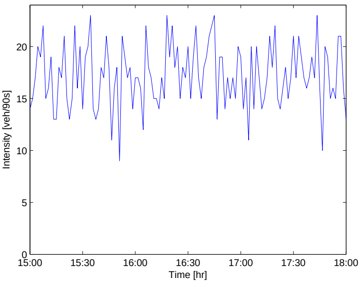


Implementation issues

Design flaws in our code:

- Asynchronous behaviour of MATLAB-AIMSUN toolbox introduces time skew – fixed data colection period 90 sec, typical T_c is 80 sec
- Predictions of intensities are quite incorrect – intensities are very noisy, problems in states close to saturation





Outline

Closed Simulation Loop

Current UTC evaluation scenario

Reality: Intersection controllers have a degree of autonomy

Preliminary tests:

- assume that reality is completely controlled by us
- we can set precisely the splits we want to
- if we do it wrong we can complain only to ourselves

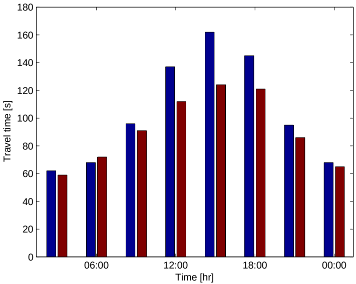
HRD sends signal plan to Aimsun, Aimsun responds with measurements of intensity and occupancy.

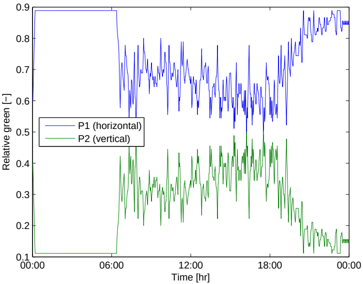
Favourable Situation

Adverse fixed-control settings

Initial phase image (splits) are not optimally set.

Typical results:

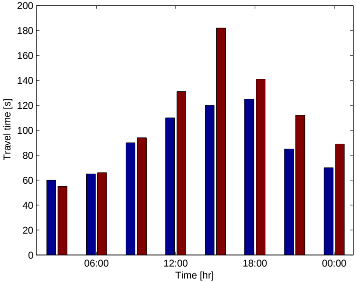


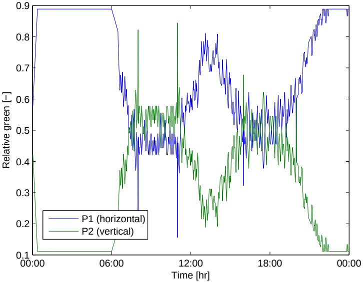


Problems
Near-optimal fixed-control

Use optimum green settings and try to improve on them.

Typical results:





Problems
Identified causes

Model:

- Queue correction by filter in case of short green signal
- No influence of occupancy on queue length

Control:

- Intensity predictions are not reliable

Model defficiences

Incomplete link between queue length and occupancy

Occupancy measurement $O_{\text{in},i,k}$ can influence queue length $\xi_{i,k}$ only in saturated conditions:

$$\xi_{i,k+1} = \delta_{i,k}\xi_{i,k} + (\delta_{i,k}S_i + (1-\delta_{i,k})I_{\text{in},i,k})z_{i,k} + I_{\text{in},i,k}$$

But what if the saturation flag $\delta_{i,k}$ has not been properly identified?

Model defficiences

Filter covariances

Shock waves and strong left turn demands may cause temporary blockage of an intersection.

If covariances are not set properly

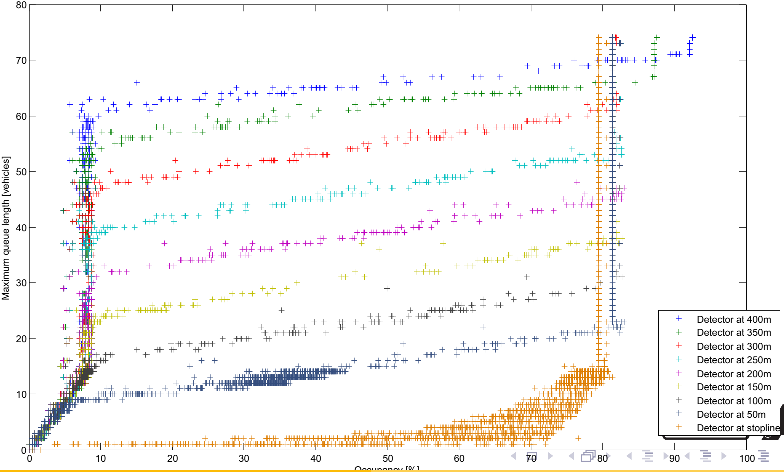
- both I_{in} and I_{out} are low
- hence queue length is also low

But in fact, O_{in} may be above 90%.

Model defficiences

Occupance-Queue formula

Can be simplified to $O_{i,k+1} = \kappa \xi_{i,k} + \lambda$



Controller defficiences

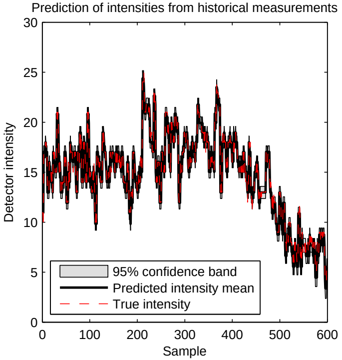
Inaccurate prediction of source intensities

Optimalisation on horizon needs accurate intensity predictions.

Measurements are **very** noisy.

Several models tested:

- linear extrapolation
- AR
- Gaussian mixtures
- SVM regression
- **Gaussian processes**



Outline

Outlook into Future

Software:

- ELS3/Aimsun and HRD/Aimsun merge
- Port to slow industrial PCs
- Spring 2008: Evaluation at Prague City Hall
- Fall 2008: Field testing

Model:

- Modifications inspired by conservation-law approaches
- Better initial variance
- Better prediction of intensities
- Re-evaluate the queue–occupancy link