Validation of the Urban Traffic Control System HRDS and Some Remarks about Queue Length Estimation

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Outline

1 Basic Concepts and Quantities
2 HRDS (Urban Traffic Control System from UTIA)
- State end of 2007

3 Development in 2008
- Intersection controller
- HRDS
- Bugs
- Model Defficiencies
- Controller Defficiencies

4 Simulated Validation Results
5 Occupancy-Queue Relation
- HRDS

6 Conclusions

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Introduction
Quantities

Measured by inductive loops / video

Intensity:

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

Occupancy:

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

Turning rate: percentage of the cars passing the stop-bar to a particular outgoing arm

Introduction
Quantities

Saturation flow S:

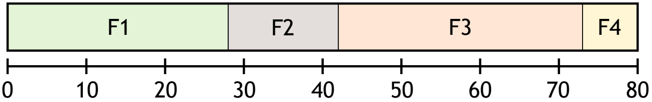
- maximum flow at an arm
- determined by construction parameters, turning rate and opposite flow intensity
- typical value around 1900 veh/hr

Cycle length T_c:

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

Green split:

- ratio of particular phases in a signal plan



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HRDS
General

Initial assumptions:

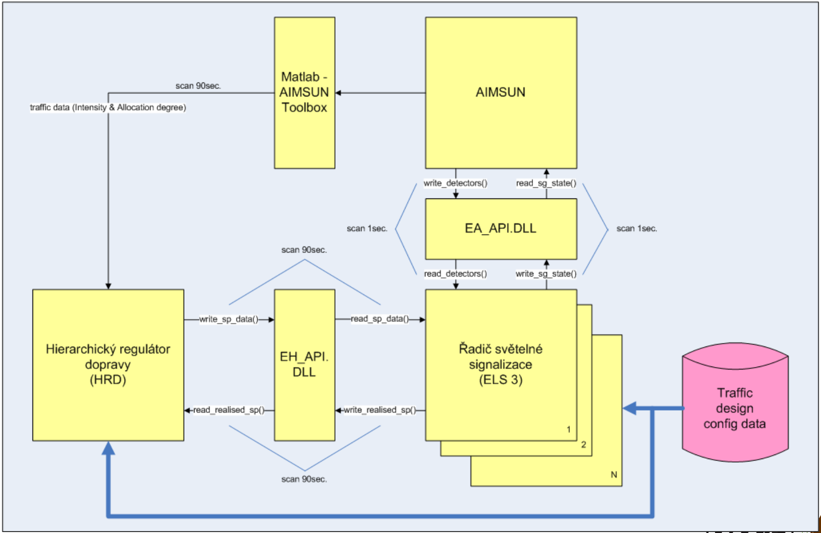
- long arterials
- enough strategic detectors
- simple macroscopic approach

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

Intersection controllers maintain a degree of autonomy

System architecture



Project state at the end of 2007

ELS3 intersection controller ported to `win32`.

Written APIs for

- communication between external controller and ELS3 (`eh_api`)
- communication between ELS3 and Aimsun (`ea_api`)

Successful initial demo of `toolboxELS3` (Matlab + ELS3 + Aimsun) using intersection 5.068 (Praha-Smíchov, Zborovská × V botanice).

Some work on interfacing `toolboxELS3` to HRDS.

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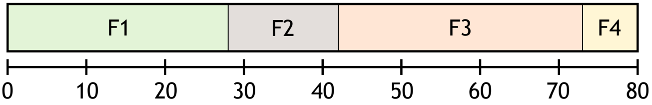
ELS3 Controller

ELS3 modified to accept frame plans (*rahmenpläne*) and behave as close as Simens C400 as possible:

- initial wish from HRDS on phase lengths, e.g. $[40, 20, 20]$
- rotation of the plan to start at GSP
- switch to the plan when TX=GSP
- grant local dynamics to signal group
- send back the real length of signal groups, e.g. $[37, 16, 16]$ or even $[80, 0, 0]$.

Configuration tables and signal timing done at Eltodo DS.



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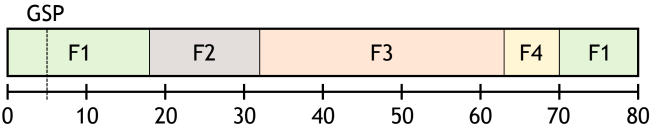

HRDS

No chance to generate cars and use ELS3 at the same time (limitation of the `ASYNtoolbox`):

- need to reshape the main loop of HRDS
- need for additional toolbox ⇒ `toolboxVGS` + API DLLs + Getram extension

`toolboxVGS` provides

- independent vehicle generation
- offline signal group control
- Aimsun statistics collection

Matlab is a ↯ nightmare ↯ when it comes to complex code changes . . .

Sources of bugs
General

Possible bug sources

- AIMSUN (hard to eliminate)
- ELS3 (need Eltodo to do it, but it's OK)
- AIMSUN-ELS3 API library
- HRDS-AIMSUN API library
- HRDS
- Matlab

ELS3 bugs

ELS3

- frame plan switching point unreachable
- switching blocked by invalid condition
- wrong assignment of detectors

Takes some time to diagnose bugs, quick workarounds
These are just technicalities

API bugs

Aimsun-ELS3 and HRDS-Aimsun interfaces

Written from scratch ⇒ not completely tested in 2007

Interfaces

- communication over SHM ⇒ many race conditions possible
- synchronisation problems
- data overflows
- bind too deep into Matlab kernel (crashes, freezes, . . .)

Pathetic `loadlibrary()` interface (no structures possible, no decent support for 64bit code)

Every demonstration of a bug usually results in reboot.

Problems with the model

And attempts to address them

The model has been designed to control queues in saturated state ⇒ problems in free flow state

Experimental evidence of queue length model problems

- input intensity ≡ external disturbance
- wild guesses of queue lengths (integrator)
- no chance to use occupancy to correct queue length
- no chance to detect blocking at approaches to intersection
- abrupt intensity changes, 90s measurement period too long

Improved model ⇒ see poster presentation

Weak points of the controller

And attempts to address them

Linear programming using model prediction up to *h* steps.

- no chance to address changes in saturation
- no chance to address uncertainty in intensity input
- constant weights

Queue Weight Selection

LP: $\arg\min_x \mathbf{w} \cdot \mathbf{x}^T$ with constant weights. Hence, large Δx_i will be favoured.

But: long queues can discharge quickly for high saturation flows.

$\Rightarrow$ Weight should depend on saturation flow.

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Simulated Validation at Zličín

Calibration of Aimsun

Microscopic simulation model needs to be calibrated and validated

- driver behaviour
- turning rates
- section parameters

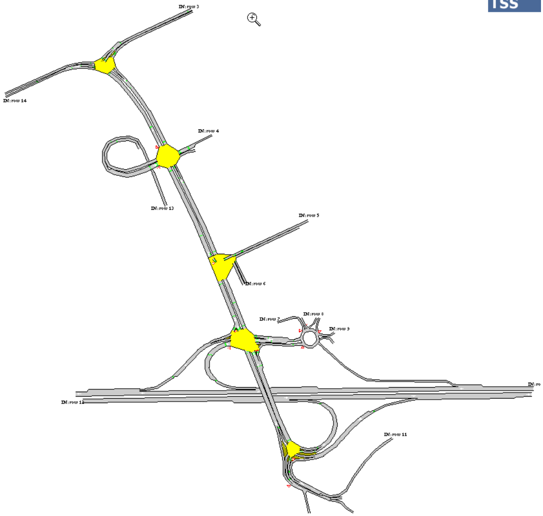
Iterative process:

1. Set parameters
2. Load known inputs with known detector responses
3. Simulate and evaluate

Manual tweaking – current errors up to 20%

Simulated Validation at Zličín

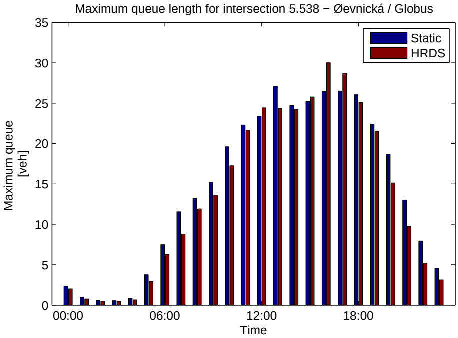
Scheme of the network

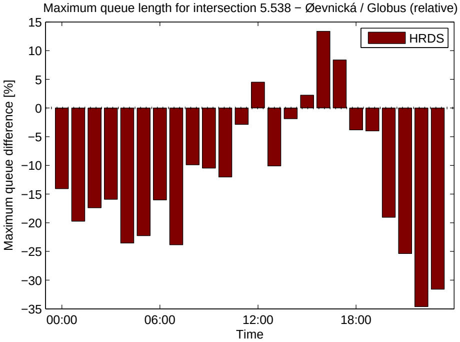


Simulated Validation at Zličín

Example of traffic jam

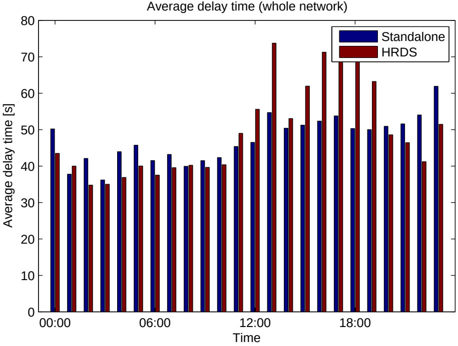
Simulated Validation at Zličín
Queue Length

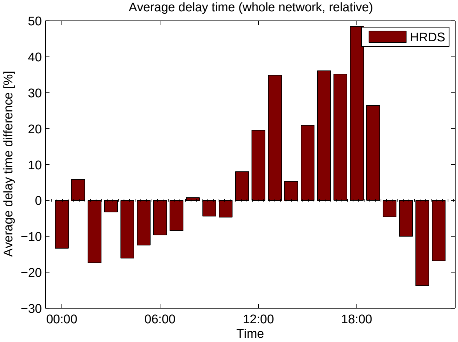




Comparing simulation using autonomous ELS3 vs. HRDS

Validation at Zličín
Average Delay





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Occupancy-queue relation
As modelled in HRDS

Linear, occupancy depends on previous occupancy and queue length:

$$O_{k+1} = \kappa\, O_k + \beta\, \xi_k + \lambda$$

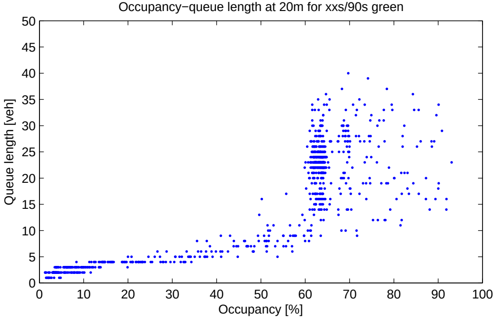
with coefficients κ, β, and λ either estimated or pre-set.

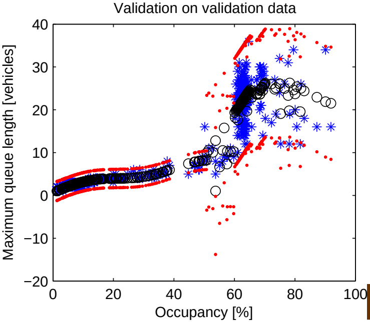
Initial experiments in 2007 with Juš Kocijan.

Occupancy-queue relation
Gaussian Process Model

Aimsun simulation of a single-lane approach
Detectors 5m apart, 3m long
Influence of

- detector size (zero speed–zero occupancy)
- green length





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Conclusions

- Another toolbox for HRDS
- Validated microscopic model
- No decisive data for the evaluation documentation
- Model changes, filter tuning (covariances)