Remarks on Traffic Signal Coordination (Progression)

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Introduction: Traffic signals in a network

• Car-drivers: traffic signals do always display red when I arrive there
• To remedy this, traffic signal co-ordination is attempted
• Most famous: the green wave
• Easy to understood: in a space-time diagram, a platoon of vehicles progresses from one traffic light to the next
• Unfortunately easy to understood: one may think that doing the same in networks is simple, too.
• Not true, of course
A green wave 2019

- **Time**
  - Signal #1
  - Signal #2

- **Space**
  - Red time $r$
  - Green time $g$
  - Offset $\phi$
  - Cycle time $c$
1929:

By City of San Francisco - Public domain (via Eric Fischer), https://commons.wikimedia.org/wiki/index.php?curid=34715929
Extension to a network...

• Is complicated, only in rare special cases (regular grid networks, other preliminaries) this can be done in a simple manner
• In real networks, this runs into a fairly complicated optimization problem which is, as far as I have understood, NP-complete to solve (Little, 1966), (Gartner, Little, & Gabbay 1977)
• In 2004, Gershenson came up with the idea of a self-organized traffic signal system (SOTL)
• There is a lot of additional work on this especially by (Lämmer, 2007)
• Idea is: let these signals alone, together with the appropriate control mechanism they will find some self-organized optimum
The Great Plan

• SOTL draw criticism. Nicely put by Bernhard Friedrich (in German, unfortunately) where he put
• “The Great Plan” versus “the jungle principle”
  (translation by me, may be inadequate)
• Bernhard’s Great Plan is charming: such a plan (has some similarity to a bus schedule) forces traffic flow into a pattern of platoons for which down-stream traffic signals can be timed optimally
• Another kind of self-organization, so to speak, but forced by the plan laid out by the traffic management center

From: https://www.athenstransit.org/lines-5-6/
The Big Question

• What is better?
• The following is a kind of test; one may have other things in mind, and there are some things in SUMO’s developer pipeline that can be used to test these ideas more thoroughly.
• Today: stick to the more traditional approach, no i.e. I do not dive into SOTL
Putting these ideas to a test
The networks

- Can all being done with SUMO’s tool-box:
- Use artificial networks with an artificial demand:
  - netgenerate
  - randomTrips.py
- Exception: used an additional network from Berlin center as well
- Create traffic signals for these networks
  - netconvert – this yields the case default (it is bad, but easy to outperform)
- Do the signal planning with:
  - tlsCycleAdaptation.py (compute cycle time and green splits)
  - tlsCoordinator.py (compute the offsets between the signals)
- Actuated signal (well, this might count as SOTL, but...)
The demand

- Generated with randomTrips.py
- All in all 5 levels of demand
  (randomTrips.py) has a parameter
  \( p \) (period) = (8, 4, 2, 1, 0.75),
  which generate vehicles with equidistant
  departure times \( p \) seconds apart
- No user-equilibrium computed
- Delay-times depend on demand (of course)
The traffic signal settings

• Base-net created without traffic signals
• netconvert (...) --tls.default-type static ➔ SUMO’s fixed time signals
• netconvert (...) --tls.default-type actuated generates actuated signals
• For fixed time signals, tlsCycleAdaptation.py produces Webster-optimal cycle and green times for each intersection
• From this, the maximum cycle time $c_{\text{max}}$ for the network can be picked...
• All signals forced to $c_{\text{max}}$ for co-ordination
• Meanwhile, tlsCycleAdaptation.py has a new option that does this
• Then, tlsCoordinator.py computes a set of good offsets (most likely not optimal)
Four scenarios

• Fixed time (SUMO’s default) “fix”
• Webster optimized splits and cycle time “fixSC”
• In addition, with co-ordination “fixSCO”
• Actuated “actd”
The most import things last

• The networks have two lanes in each direction, that was done intentionally
• Cars are identical (except for the Berlin scenario), but their preferred speed is drawn from a distribution with speedDev = 0.1
• Vehicles drive stochastically, parameter sigma of the SK model is at SUMO’s default value (0.5)

⇒ Strong platoon dispersion, not unrealistic:

Taken from Gartner, Little, & Gabbay
Real-life speed distribution (Ernst-Ruska-Ufer, 2015)

• Data between 20…80 km/h (138 max!)
• Mean = median = 59 km/h (50 km/h SL)
• Sd = 6 km/h \( \Rightarrow \) speedDev = 0.1
• Interquartile: 55…63 km/h

Next upstream signal: ~ 600 m

Sources: openstreetmap.org, own plot
Results
Example of a network (disturbed grids, 400 m)

- 4 x 2, ..., 14 x 8
- (4, 6, 10, 14) x (2, 4, 6, 8) x 5 repetitions
Main result

• Webster is slightly better than SUMO’s default: it cuts some of the large delay times
• Co-ordination helps Webster: getting slightly better
• But: actuated control is better, despite the fact, that demand is constant during one run
• (Difference might be even bigger for time-varying demand)
• Distribution of 80 mean values
Berlin Center

- Real-life network
- 120 traffic signals
- 242 km network length
- 190,000 trips,
- Created by TAPAS + one-shot
- (So far, no check against counts)
- Network is at the border of capacity
- 24 hour simulation, time-dependent demand
Results are similar…

• But not the same.
• Difference between fixed and Webster larger
• Small gains with co-ordination
• Small gains with actuation
Conclusion & Outlook

• In real world chaos, the Great Plan seems to be underperforming
• In the ideal case of small platoon dispersion, it may have an edge
• If results can be transferred to real life, then running all signals actuated is sufficient to yield smooth traffic in a city
• And: from single intersection control it is known that even actuated traffic controllers can be outperformed by something like AGLOSA…
• Which adds a short-term prediction & planning to the objective function
Conclusion & Outlook

• But, you know: if you improve traffic signals, what will happen?
• (Transportation planners curse)

• Thank you for listening!