Traffic-Light Control for Emergency Vehicles

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Motivation
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20 per cent of emergency patient deaths blamed on traffic jam delays
Jan 16, 2017

MORE THAN 20 per cent of patients needing emergency treatment have died on their way to hospital because of delays due to traffic jams and uncooperative motorists, National Institute of Emergency Medicine (NIEM) secretary-general Anucha Sethasathan said.

Thailand - 20% of death due to traffic jam - Jan 2017!
Problems and Goals

Big picture - Mobility and Public Transportation
Problems and Goals

Reduce the delay (time loss) of the EV in traffic
Using traffic light (TL) preemption

Do not impact (too much) other vehicles!
Research challenges

- Does green light mean vehicles passing through?
- Is it an optimization problem?
- Is it NP-Hard?
- Can we use probabilistic modeling?
Related Work

Proximity sensors ✗
Focus on intersection ✗
Unrealistic scenarios ✗
Related Work

Different EVs, with different routes ✗
Hard-to-deploy infrastructure ✗
Lack of formal properties of safety for the entire EV route ✗
Focus on solution!!!
Proposed Solution - TPN

Directed Graph

- Useful to model distributed, parallel and concurrent systems
- Places, transitions, and directed edges
- Transitions can be fired when tokens are present in their input places
- Timed Petri Net - minimum time to fire a transition
Proposed Solution - TPN

Control of all TLs in the EV route
Proposed Solution - TPN

Individual control of a TL

\[ T_{2i} = \begin{cases} 
0, & \text{if } \frac{d_{TLi}}{ASLpath_i} \leq \epsilon \text{ or } ASPath_i \leq \delta \\
\max\left\{ \left( \frac{d_{TLi}}{ASLpath_i} - t_{flush_i} \right) \times (1 - Opath_i), 0 \right\} 
\end{cases} \]  
(1)
Why is it safe?

i. It executes at most one preemption action

ii. It does not restore the state of any $TL_i$ before its preemption

iii. It executes at most one restore action

The token that gets to $P_3$ arrives only via $P_0$, which receives a token only once from the Initial Transition for $TL_1$ or from $T_1$ of $TL_{i-1}$ for all $TL_i$, $2 \leq i \leq N$. Because the preemption action happens when the token gets to $P_3$, a control block executes at most one preemption.

For properties (ii) and (iii), the token must get to $P_6$ via $T_4$. As $T_4$ depends on $P_4$ and $P_3$, a control block does not restore the state of a $TL_i$ before $P_3$ triggered the preemption. Likewise, because $P_4$ gets only one token, the restore action happens at most once.
Performance Evaluation

- SUMO Simulator
- SP and NY
- All routes were generated using the OSMWebWizard tool
- Cars, trucks and motorcycles
**Performance Evaluation**

- A vehicle was chosen to be the EV in each city (crossing 65 TLs)
- Routes
  - EV: fixed
  - Other: dynamic
- Two other algorithms: RFID and Fuzzy
- 60 independent simulation runs

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(a) Sao Paulo

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(b) New York
Simulation Results - Time Loss - No Preemption

(e) SP

(f) NY
Simulation Results - Time Loss Improvement - TPN × RFID And Fuzzy

(g) SP

(h) NY

(i) SP

(j) NY
Limitations and Future Work

- Use more than one EV (conflict policies)
- Allow improvement beyond 100%
  - by allowing that the EV speed be greater than the maximum speed limit of the streets
- Integrate our solution with the InterSCity middleware
  - real versus simulated time
- Go deep on Research challenges
Final Considerations

- Source code at https://github.com/smartcity-tpn-preemption/tpn-preemption
- Comparison example
  - SP-1 https://youtu.be/_AgZ3HyDgCs
  - SP-5 https://youtu.be/7r_1yiemsE0

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