Recurrent and Non-recurrent Congestion Based Gridlock Detection on Chula-SSS Urban Road Network

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Contents

- Motivation
  - Traffic bottlenecks
  - Recurrent and non-recurrent congestion
  - Upstream-downstream congestion propagation

- Objectives

- Background
  - Literature review on recurrent and non-recurrent congestion
  - Chula-Sathorn SUMO Simulator (Chula-SSS)
  - How to simulate gridlock?
  - How to characterize gridlock?
  - The scenario used on Chula-SSS and observation results

- Conclusion

- Acknowledgements
Traffic bottlenecks

imbalance supply and demand at intersection
Traffic bottlenecks (cont’d)

Normal traffic bottlenecks[1] Unforeseen traffic bottlenecks

- Accidents
- Severe weather condition
- Road maintenance

Recurrent congestion

- Stop and go traffic pattern daily in morning and evening rush hours
  
  e.g. from school buses and parent vehicles to drive their children to-and-from schools

- Disorder normal traffic flows and reduce road capacity
- Spread negative impacts to neighbouring upstream and downstream links
- Reduce traffic flow efficiency in complex urban road network
- Lead to formation of congestion gridlock

Non-recurrent congestion

- Unforeseen, unexpected events
  
  e.g. bad weather, vehicle collision
Upstream-downstream congestion propagation

Propagation of bottlenecks can lead to a large-scale urban network gridlock [10]

Objective

- To detect recurrent and non-recurrent cases based gridlock with upstream ~ downstream nearby detectors at every intersection in the loop by using different combinations of traffic jam length and mean speed conditions during the green time.
Literature review on recurrent and non-recurrent congestion

- Analysis congestion bottleneck core link and its neighbouring links by clustering links based on link speed ranks [1]

- Regression model for urban traffic networks by using the combinations of traffic indicators like link traffic flows, link lengths and signal phase cycle time [2]

- Non-recurrent congestion detection method with spatio-temporal clustering on high link journey time [3]

Literature review on recurrent and non-recurrent congestion (cont’d)

- Percentile and space-time scan statistics for non-recurrent incident detection with link journey time lognormal distribution [4]

- Travel demand effects on non-recurrent incident detection methods by using estimated link journey time [5]

- Data mining approach to define traffic volume parameters and analyze impact duration with time and season features [6]

Literature review on recurrent and non-recurrent congestion (cont’d)

- An automatic traffic incident detection and locating method on urban road segment in consideration of lane-changing characteristics [7]

Bangkok (Thailand)

- TomTom Traffic Index (Aug, 2016)
  - Bangkok is the most congested city in Asia
  - 2nd most congested city globally
  - Extra travel time 64 min per day
- Workers based outside the city drive to and from work with different vehicle types (cars, bus, motorbikes)
- Rush hours from 6:00 to 9:00 in morning and 3:00 to 7:00 in evening
Sathorn Area

❖ Densely populated part of city
❖ Link between residential area and business area
❖ 150,000 vehicles ~ every weekday
❖ 55,000 traveling vehicles ~ morning/evening rush hours
❖ Spillover effect on nearby streets and surrounding areas
Chula-Sathorn SUMO Simulator (Chula-SSS)

- Chulalongkorn University's Sathorn Model project
- Calibrated datasets cover morning and evening rush-hour periods with over 55,000 simulated vehicles
- 2375 intersection nodes
- 4517 edges with left-handed driving
- 10 signalized intersections

Critical region in simulated Sathorn road network

- Sathorn critical region with 5 intersections
- Accumulate summed data during simulation time ~ traffic flow, mean speed, jam length from lane area detectors [9] in the whole loop

Calibrated Chula-SSS loop-based fundamental diagrams
Recurrent-case with **two extra routes**

![Map showing routes between Assumption College, Assumption Convert Silom, Bangkok Christian College, and Sathorn Thai Rd.]

- **Assumption College**
- **Assumption Convert Silom**
- **Bangkok Christian College**
- **Sathorn Thai Rd.**

1. **Chareon Krung Rd.**
2. **Chapom Rd.**
3. **Sarawak Rd.**
4. **Silm Rd.**
Turning movements at intersection in real case
Original Chula-SSS with two extra routes to create recurrent-case

<table>
<thead>
<tr>
<th>Route</th>
<th>Time</th>
<th>Flow (v/h)</th>
<th>Total Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7:00 AM - 8:15 AM</td>
<td>425</td>
<td>531</td>
</tr>
<tr>
<td>2</td>
<td>6:15 AM – 6:45 AM</td>
<td>300</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>6:45 AM - 7:15 AM</td>
<td>300</td>
<td>150</td>
</tr>
</tbody>
</table>

Route 1 ~ 2125 v/h
Route 2 ~ 1500 v/h
Non-recurrent case with lane closure

- 2 lanes for each direction
- Blockages
  - Bus stops
  - Illegal parking (~taxis, tuktuks)
- One out of two lanes (160 m) on the road segment for two times (22500 s to 23700 s and 25200 s to 26400 s) with the duration of 20 mins each

https://www.google.com/maps/
Comparison of loop-based fundamental diagrams

Recurrent-case

Non-recurrent case

Traffic flow (v/s)

Zero flow

Halting vehicle speed

Halting speed vehicle

Mean speed (m/s)

Time (s)

6:00 AM 7:00 AM 8:00 AM 9:00 AM

6:00 AM 7:00 AM 8:00 AM 9:00 AM

233 v/s

213 v/s
Comparison of loop-based fundamental diagrams (cont’d)

Recurrent-case

Non-recurrent case

long queue

short queue
- Overall network capability
  - 233 v/s ~ recurrent case
  - 213 v/s ~ non-recurrent case (incident injection)
- Incident injection does not hurt the jam situation significantly higher that its norm
How to characterize gridlock in practice?

- upstream-downstream detectors in all intersections within potential gridlock loop are in jam state
- 100 m ~ upstream
- 50 m ~ downstream
How to characterize gridlock?

- *jam state of each intersection* *i* *in the whole loop* *L*,

  - mean speed $\leq 5$ km/h
  - jam length $> 80\%$ of detector length for each upstream and downstream pair

**gridlock status** $1$ ~ all intersections $i \in L$ are in the *jam state* during green time

**gridlock status** $0$ ~ otherwise
### Number of time steps with gridlock detected by each condition in every 5s of simulation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Recurrent</th>
<th>Non-recurrent</th>
</tr>
</thead>
<tbody>
<tr>
<td>upstream-speed, downstream-speed</td>
<td>103</td>
<td>70</td>
</tr>
<tr>
<td>upstream-speed, downstream-jam</td>
<td>105</td>
<td>70</td>
</tr>
<tr>
<td>upstream-speed, downstream-speed+jam</td>
<td>103</td>
<td>70</td>
</tr>
<tr>
<td>upstream-speed+jam, downstream-speed</td>
<td>103</td>
<td>70</td>
</tr>
<tr>
<td>upstream-speed+jam, downstream-jam</td>
<td>104</td>
<td>70</td>
</tr>
<tr>
<td>upstream-speed+jam, downstream-speed+jam</td>
<td>103</td>
<td>70</td>
</tr>
<tr>
<td>upstream-jam, downstream-speed</td>
<td>110</td>
<td>80</td>
</tr>
<tr>
<td>upstream-jam, downstream-jam</td>
<td>120</td>
<td>87</td>
</tr>
<tr>
<td>upstream-jam, downstream-speed+jam</td>
<td>110</td>
<td>78</td>
</tr>
</tbody>
</table>
Conclusion

❖ Recurrent and non-recurrent based gridlock

❖ Measurable gridlock characteristics in terms of traffic jam length and speed from both upstream and downstream links of corresponding intersections

❖ Investigating gridlock detection and prediction conditions with machine learning based classification algorithms (ongoing work)
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