Leveraging SUMO for Real-World Traffic Optimization

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Addressing real-world traffic challenges utilizing SUMO simulations

Importance of testing and validating traffic management solutions before deploying in the field.
Agenda

- Terminology
  - NoTraffic Technology
  - ATSPM

- Realistic Micro-Simulation in SUMO
  - SUMO Network
  - Simulation Scenario
  - Traffic Light Controllers
  - Calibration

- Real-world application of SUMO
NoTraffic Overview
NoTraffic Smart & Connected Intersection

- **4x Sensor Units**
  - 3x Standard
  - 1x V2X Ready

- **Nexus Unit** connected to the traffic signal controller

- **Cloud-Based Platform**
Detection & Tracking

Powered by AI algorithms – Detecting Vehicles & Vulnerable Road Users

- Data sampled at $f > 1$ Hz
- Classification: car, bus, truck, pedestrian, bicycle and more
- Position: lane, distance from stop bar, direction, speed
- Yielding a robust and extensive dataset
- This dataset is used for real-time optimization and data analytics

Sensor Units
Sensor Provides Trajectories Per Approach

Camera View

Trajectories from video

Lanes & connections

Sensor Units
Automated Traffic Signal Performance Measures

- Traffic counts
- Average delay per vehicle
- Arrival on Green - AoG
- Split Failure
Realistic Micro-Simulation in SUMO
Key steps

- SUMO Network
- Simulation Scenario
- Traffic Light Controllers
- Calibration
Network Layout Challenges

Real World

OSM

NoTraffic
SUMO Network Generation

Standard single intersection

Sensor view:
- Lanes
- Trajectories
- Intersections locations

SUMO Network generation based on:
- Nodes, edges, connections

SUMO view:
- Lanes
- Connections
- Nodes

netconvert
--node-files=model.nod.xml
--edge-files=model.edg.xml
--connection-files=model.con.xml
--output-file=model.net.xml
Real-World Scenario

Counts distribution

⚠ Counts by 1 min distributed uniformly:
   • ~40–50% calibration success rate

⚠ Counts by 1 fps:
   • ~70–80% calibration success rate
Software-in-the-loop (SIL)

Main components

- **SUMO:**
  - detected & crossed road users

- **Virtual Controller:**
  - Integrated controller configuration
Calibration Key Steps

- Metrics for calibration:
  - Average delay
  - Arrivals on Green
  - Counts
- Car-Following model selection (Weidemann 99 model)
- Input parameters for calibration
- Calibration method
## Calibration - Input parameters

- **Standard parameters:**
  - Speed
  - Acceleration
  - Tau

- **Additional parameters:**
  - `startupDelay`
  - `jmDriveAfterYellowTime`
  - `CC2`

### Parameter Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Value</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1 (tau)</td>
<td>1.2 s</td>
<td>0.5 s</td>
<td>2.5 s</td>
<td>Desired headway time between lead/prioritized and following vehicles.</td>
</tr>
<tr>
<td>CC2</td>
<td>8 m</td>
<td>1 m</td>
<td>10 m</td>
<td>Following variation distance.</td>
</tr>
<tr>
<td>CC8 (accel)</td>
<td>2.0 m/s²</td>
<td>0.5 m/s²</td>
<td>5.0 m/s²</td>
<td>Standfill acceleration.</td>
</tr>
<tr>
<td>minGap</td>
<td>2.5 m</td>
<td>0.5 m</td>
<td>5 m</td>
<td>Empty space after leader.</td>
</tr>
<tr>
<td>desiredMaxSpeed</td>
<td>Varies by road user</td>
<td>1.39 m/s</td>
<td>50 m/s</td>
<td>Road user speed by type.</td>
</tr>
<tr>
<td>startupDelay</td>
<td>0 s</td>
<td>0 s</td>
<td>3 s</td>
<td>Delay time before starting to drive after having had to stop.</td>
</tr>
<tr>
<td>jmDriveAfterYellowTime</td>
<td>-1 s</td>
<td>-1 s</td>
<td>5s</td>
<td>Violation yellow light if the light had changed more recently than the given threshold.</td>
</tr>
</tbody>
</table>
Calibration – Method

- Simple grid search on input parameters permutations.
- Error between simulation vs. field ATSPMs is calculated by following steps:

<table>
<thead>
<tr>
<th>Step</th>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values scaling</td>
<td>[ E_p = \frac{e_p}{M - m}, O_p = \frac{o_p}{M - m} ]</td>
<td>( o_p = ) unscaled observed metric in simulation averaged over the entire scenario period per phase&lt;br&gt;( e_p = ) unscaled expected metric in field averaged over the entire scenario period per phase&lt;br&gt;( M = ) Maximum metric value per phase&lt;br&gt;( m = ) minimum metric value per phase</td>
</tr>
<tr>
<td>Metric error calculation per phase</td>
<td>[ \chi^2 = \sum_{p=1}^{n} \frac{(O_p - E_p)^2}{E_p} ]</td>
<td>( O_p = ) scaled observed metric in simulation averaged over the entire scenario period per phase&lt;br&gt;( E_p = ) scaled expected metric in field averaged over the entire scenario period per phase</td>
</tr>
<tr>
<td>Total Error</td>
<td>[ error = \frac{1}{n} \cdot \sqrt{\chi^2_{total.count}} + \frac{1}{n} \cdot \sqrt{\sum_{p=1}^{n} \chi^2_{avg.delay(p)}} + \frac{1}{n} \cdot \sqrt{\sum_{p=1}^{n} \chi^2_{AoG(p)}} ]</td>
<td></td>
</tr>
</tbody>
</table>

- Input parameters that yield the minimum error and meet the specified thresholds are selected.
Calibration – Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1</td>
<td>1.2 s</td>
</tr>
<tr>
<td>CC2</td>
<td>4 m</td>
</tr>
<tr>
<td>CC8</td>
<td>2.5 m/s²</td>
</tr>
<tr>
<td>minGap</td>
<td>1.4 m</td>
</tr>
<tr>
<td>desiredMaxSpeed</td>
<td>17.89 m/s</td>
</tr>
<tr>
<td>startupDelay</td>
<td>0 s</td>
</tr>
<tr>
<td>jmDriveAfterYellowTime</td>
<td>1 s</td>
</tr>
</tbody>
</table>
Case Study
Steps to solve field issues

- Reproduce the issue in simulation 🎯
- Solve the issue in simulation 🌟
- Verify the solution is stable 🤝
- Deploy in the field with confidence 👀
- Monitor 🌐
Case Study: Arizona, USA – May 2023
Reproduce the issue

- Using the calibrated model and the scenario from the time of the incident
Solve the issue in simulation

Several strategies were tested in our optimization algorithm
The one we used is called **flush queue**
Verify the Solution is Stable
Deploy & Monitor

Avg. delay: field data - before vs. after flush queue implementation

Average delay: 15 minutes interval

Average delay: 1 hour interval

Before

After

Time of day

Average delay [sec]

PM peak

Average delay [sec]
Conclusion

- Quality In, Quality Out (QIQO)
- SUMO plays a vital role in our system and is integral to our business operations.
- Examples Await—Let’s Watch!
Customer Case Studies
Thank You!

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