Integration Traffic Signal Control
From Synchro to SUMO

Yiran Zhang
May 15, 2024
Outlines

> Introduction & Motivation
> Traffic signal control integration
> Conclusion & Future Step
Introduction & Motivation

> Current traffic simulation

- **Macroscopic:** Focuses on the traffic at a low level of detail where the traffic stream is represented in an aggregated level, such as speed, flow, and density.

- **Microscopic:** Details individual vehicle and pedestrian movements, allowing for the simulation of specific behaviors like car-following and lane-changing.

- **Mesoscopic:** A hybrid approach blending macroscopic and microscopic elements, offering more detailed analysis than macroscopic models but less resource-intensive than microscopic simulations.

- **Submicroscopic:** Provides intricate details of each vehicle, including internal mechanics such as gear shifting, suitable for in-depth vehicle dynamics analyses.
> **When & Why is simulation integration needed?**

– **Large-Scale Simulations**
  o Extracting network features from existing simulations vs. manual coding

– **Multiscale Simulation Connectivity**
  o Seamless connectivity and communication across different simulation platforms are crucial for multiscale simulations.

– **Data sharing**
  o When data providers offer information from different simulation platforms, it is essential for researchers to adeptly transfer these features to maintain data integrity and relevance.
Therefore

> **The aim of this study**
  > Understand the feasibility and effectiveness of simulation integration, specifically traffic signal timing
  > Identify potential obstacles and problems

> **Case study**
  > Synchro vs. SUMO
  > Traffic signal timing
  > Study area
    > Downtown Seattle, USA
Synchro vs. SUMO

> **Synchro (widely used in public agency) → why we use synchro as feature transform**

> **SUMO**
  - "Simulation of Urban MObility" (SUMO) is an open source, highly portable, microscopic and continuous traffic simulation package designed to handle large networks. It allows for intermodal simulation including pedestrians and comes with a large set of tools for scenario creation."
Cont.

> **Current convert simulations/packages**

– SUMO Netconvert
  o Convert network to SUMO, covers
    • VISUM, VISSIM, MATsim, Shapefile, OSM
  o However
    • Manual work is suggested

– VISSIM import
  o Available to import Synchro files
  o However
    • Requires the latest version of Synchro
    • Multiple errors may occur if actual controller timing sheets not matched
Traffic signal control integration – 4 stages

1. Data Preparation
2. Connection-to-Direction Mapping
3. Signal Phase Mapping
4. Data Revision & Output
Stage 1: Data Preparation

> **Network data structure in Synchro**
  - Format: Comma-Separated Value Table (.csv)
  - Network (General settings)
  - Nodes (Geo-location of each intersection)
  - Links (Settings for links)
    - # of lanes, distance, grade, speed, direction (e.g., NB, SB)
  - Lanes (Detailed lane info)
    - Direction (NBL, NBT)
  - Timeplans (Signal timing plans for each intersection)
    - Control type, cycle length, offset
  - Phases (Signal phases each intersection)
    - Min/Max Green, Yellow, Red, BRP
Stage 1: Data Preparation

> Network data structure in SUMO

- Format: XML
- Configuration (General settings)
- Edge (setting for edges)
  - Length, geo-location, ROW
- tlLogic (traffic light logics)
- Junction (settings for intersections)
  - Intlanes, location
- Lane & Connection (relationship between two lanes)
  - Fromlanes, tolanes, direction
## Synchro vs. SUMO

<table>
<thead>
<tr>
<th>Features</th>
<th>Synchro</th>
<th>SUMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Link</td>
<td>X Ped lanes</td>
<td>✓ Ped lanes</td>
</tr>
<tr>
<td></td>
<td>X Bus lanes</td>
<td>✓ Bus lanes</td>
</tr>
<tr>
<td></td>
<td>X light rail</td>
<td>✓ Light rail</td>
</tr>
<tr>
<td></td>
<td>Link</td>
<td>Edge</td>
</tr>
<tr>
<td></td>
<td>Lanes</td>
<td>Lane &amp; Connections</td>
</tr>
<tr>
<td></td>
<td>Nodes</td>
<td>Junction</td>
</tr>
<tr>
<td>Signal control</td>
<td>Timeplans &amp; Phases</td>
<td>tlLogic</td>
</tr>
<tr>
<td>General settings</td>
<td>Network</td>
<td>configuration</td>
</tr>
</tbody>
</table>
Stage 2: Connection-to-Direction Mapping

<table>
<thead>
<tr>
<th>[Lanes]</th>
<th>RECORD INTID</th>
<th>NBL</th>
<th>NBT</th>
<th>NBR</th>
<th>NBR2</th>
<th>SBL2</th>
<th>SBL</th>
<th>SBT</th>
<th>SBR</th>
<th>EBL</th>
<th>EBT</th>
<th>EBR</th>
<th>EBR2</th>
<th>WBL2</th>
<th>WBL</th>
<th>WBT</th>
<th>WBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upl Node</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Dist Node</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Lanes 6</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Phase 1</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PermPhas 6</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>[Timplans]</th>
<th>RECORD INTID</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control 1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Cycle Len</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Offset</td>
<td>6</td>
<td>52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>[Phases]</th>
<th>RECORD INTID</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRP</td>
<td>6</td>
<td>111</td>
<td>112</td>
<td>211</td>
<td>212</td>
<td>121</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>MinGreen</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>MaxGreen</td>
<td>6</td>
<td>8.5</td>
<td>17.5</td>
<td>21.5</td>
<td>6.5</td>
<td>19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VehExt</td>
<td>6</td>
<td>3</td>
<td>0.2</td>
<td>2</td>
<td>2</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>6</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>AllRed</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

```xml
<tlLogic id="0" programID="my_program" offset="0" type="ac"
  <param key="max-gap" value="3.0"/>
  <param key="detector-gap" value="2.0"/>
  <param key="passing-time" value="2.0"/>
  <param key="vTypes" value=""/>
  <param key="file" value="NULL"/>
  <param key="freq" value="300"/>
  <phase duration="31" minDur="5" maxDur="45" state="GrGr"
  ...
</tlLogic>
```

UNIVERSITY of WASHINGTON
Intelligent Urban Transportation Systems
Stage 2: Connection-to-Direction Mapping

> Signal timing rule in SUMO
  - Numbered in a clockwise pattern starting from 0 to 12 o’clock
  - Pedestrian phases is specified after vehicle phases
Stage 2: Connection-to-Direction Mapping

Start

- Find all inbound directions from Synchro
- Find all unique inbound edges for an intersection
- Calculate (X2-X1), (Y2-Y1), Slope
- Find all candidates for inbound direction

Assign traffic bound to SUMO connection

Assign inbound direction to SUMO edge

Find the best match across all edges

Only 1 candidate?

Y → Add to edge list

N → End

End
Stage 3: Signal Phase Mapping

> Ring barrier control
Stage 3: Signal Phase Mapping
Signal timing setting in Synchro
Stage 3: Signal Phase Mapping
Signal setting in SUMO

```xml
<tlLogic id="0" programID="my_program" offset="0" type="actuated">
  <param key="max-gap" value="3.0"/>
  <param key="detector-gap" value="2.0"/>
  <param key="passing-time" value="2.0"/>
  <param key="vTypes" value=""/>
  <param key="show-detectors" value="false"/>
  <param key="file" value="NULL"/>
  <param key="freq" value="300"/>

  <phase duration="31" minDur="5" maxDur="45" state="GrGr"/>
  ...
</tlLogic>
```
Stage 3: Signal Phase Mapping

- Find phase combination
- Generate states for green phases
- Generate Yellow/Red phases

Diagram:
- Synchro Phase Combination
- SUMO Green Phases
- SUMO All Phases
Stage 4: Data Revision & Output

> **Logging and Analysis**
  > Logs are generated detailing intersection IDs and causes of issues for further analysis.

> **Validation and Quality Assurance**
  > Validation steps are integrated at each stage to ensure SUMO’s signal phases align with those in Synchro.
  > Checking conflict phases
  > Discrepancies are identified, indicating possible misalignments.

> **Manual Revisions**
  > Mismatched intersections necessitate manual revisions to correct misalignments.
Case Study: SUMO simulations in downtown Seattle

Original network extracted from OSM

> **Study region**
  - North: Mercer St
  - South: Atlantic St
  - West: Alaskan Way
  - East: 12th Ave

> **Available network feature**
  - Pedestrian lane
  - Bus stop
  - Link light rail
  - TAZ
Case study
Diverse intersections in Downtown Seattle
Results

Synchro

SUMO

UNIVERSITY of WASHINGTON
Intelligent Urban Transportation Systems
Signal integration results

<table>
<thead>
<tr>
<th>Scenario</th>
<th># of Intersections</th>
<th>Successful Converted Intersections</th>
<th>Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dearborn Street Arterial</td>
<td>5</td>
<td>5</td>
<td>100%</td>
</tr>
<tr>
<td>Downtown Seattle</td>
<td>281</td>
<td>239</td>
<td>85.1%</td>
</tr>
</tbody>
</table>
Simulation display

168 TAZs
39286 edges
Conclusion & Future Step

> **Conclusion**
> - Proposed four-stage approach and the integration Process Examined
> - Developed a semi-automated pipeline in Python
> - Tested on two Synchro models in downtown Seattle with an 85% success rate

> **Future Step**
> - Framework Expansion
> - Algorithmic Enhancements (for higher accuracy)
> - Advanced Features (Coordinated signal control)
> - Broader Integration Goals (not just traffic signal)
THANKS!

QUESTIONS & COMMENTS?