From Automated to Manual - Modeling Control Transitions with SUMO

Leonhard Lücken, Evangelos Mintsis, Kallirroi Porfyri, Robert Alms, Yun-Pang Flötteröd, Dimitris Koutras
leonhard.lueckken@dlr.de

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TransAID - Transition Areas for Infrastructure-Assisted Driving
Outline

● A Model for Automated Vehicles

● Transitions of Control and a Model for human driving

● Traffic Management in Transition Areas – Two Use Cases
Models for automated vehicles

• ACC Car-Following Model [Milanés et al., 2014]

  i. **Speed control mode**: is designed to maintain the by the driver chosen desired speed,

  ii. **Gap control mode**: aims to maintain a constant time gap between the controlled vehicle and its predecessor,

  iii. **Gap-closing control mode**: enables the smooth transition from speed control mode to gap control mode,

  iv. **Collision avoidance mode**: prevents rear-end collisions.
Parametrized Lane Change Model

i. Variance based sensitivity analysis
   → Influential lane change calibration parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Leader gap (ego lane)</th>
<th>Leader gap (target lane)</th>
<th>Follower gap (target lane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity Index</td>
<td>$S_l$ [%]</td>
<td>$ST_l$ [%]</td>
<td></td>
</tr>
<tr>
<td>lcStrategic</td>
<td>0.39</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>lcKeepRight</td>
<td>1.08</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>lcSpeedGain</td>
<td>0.90</td>
<td>8.12</td>
<td></td>
</tr>
<tr>
<td>lcAssertive</td>
<td>59.15</td>
<td>77.03</td>
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</tbody>
</table>

ii. SUMO lane change output vs HMETC lane change data
    → Reconciliation
ToC / MRM Model

(a) Successful ToC

- Automated mode
- Take-over time
- Available lead time

TOR

„reduced performance“

error-free

headway [s]

0 1 2 3

0 1 2 3

time t [s]

0 100 200 300

0 100 200 300
Imperfect Driving

General CF Model:

\[ \dot{x}(t) = v(t) \]
\[ \dot{v}(t) = a(\Delta x(t), \Delta v(t)) \]

Perceived quantities:

\[ \Delta \tilde{x} = \Delta x + \eta_x \]
\[ \Delta \tilde{v} = v + \eta_v \]

Erroneous CF Model:

\[ \dot{x}(t) = v(t) \]
\[ \dot{v}(t) = a(\Delta \tilde{x}(t), \Delta \tilde{v}(t)) \]
ToC / MRM Model

- [https://sumo.dlr.de/wiki/Car-Following-Models/ACC](https://sumo.dlr.de/wiki/Car-Following-Models/ACC)
- [https://sumo.dlr.de/wiki/ToC_Device](https://sumo.dlr.de/wiki/ToC_Device)
- [https://sumo.dlr.de/wiki/Driver_State](https://sumo.dlr.de/wiki/Driver_State)
Traffic management in Transition Areas
Scenario 1

Service „Path advice“

TOR area | Merge area
---|---
Path provision, Lane advices | Headway advices

automated, connected | manual

RSU

05/2019 | TransAID | SUMO User Conference
Traffic management in Transition Areas
Scenario 1

Color $\sim$ speed

Color $\sim$ ToC state

MRM

Post-ToC

manual

automated
Traffic management in Transition Areas
Scenario 1

Results

- 1h random vehicle flow (LoS C ~ 1155 veh/h)
- Fleet mixes (MV-AV):
  mix 1: 70-30
  mix 2: 50-50
  mix 3: 20-80
Traffic management in Transition Areas

Scenario 2

Service „TOR distribution“

Takeover distribution

control area

Takeover accumulation

automated, connected

RS

manual

RSU

Service “TOR distribution”

Takeover distribution

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Traffic management in Transition Areas
Scenario 2

https://sumo.dlr.de/wiki/TraCI/Change_Vehicle_State
https://sumo.dlr.de/wiki/TraCI/Change_PoI_State
https://sumo.dlr.de/wiki/TraCI/Change_Polygon_State

Highlighting & polygon dynamics
Traffic management in Transition Areas
Scenario 2

Results

- 1h random vehicle flow (LoS C ~ 3234 veh/h)
- Fleet mixes (MV-AV):
  - mix 1: 70-30
  - mix 2: 50-50
  - mix 3: 20-80
Traffic management in Transition Areas
Scenario 2

Results

Without traffic management

no-AD zone
Summary

• Models:
  – New models for automated vehicles (CFModels ACC + CACC)
  – New model for simulation of control transitions
  – Driver State model

• Assessment of TM procedures:
  – Safety improvements for smoother flows at lane drops
  – Reducing perturbances by distribution of ToCs

• Upcoming:
  – Realistic simulation of communications
  – Combination of TransAID Services
  – Real world feasibility assessment
Thank you!

See also:
- Mintsis et al. 2018, *TransAID Deliverable 3.1*
- Maerivoet et al. 2018, *TransAID Deliverable 4.2*

www.transaid.eu

Funding:
EU H2020, GNo 723390
Imperfect Driving 1

General CF Model:
\[
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Perceived quantities:
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\Delta \ddot{x} = \Delta x + \eta_x
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Erroneous CF Model:
\[
\dot{x}(t) = v(t)
\]
\[
\dot{v}(t) = a(\Delta \ddot{x}(t), \Delta \ddot{v}(t))
\]
Perception errors:
\[ \eta_x(t) = c_x \cdot \Delta x(t) \cdot H_t \]
\[ \eta_v(t) = c_v \cdot \Delta x(t) \cdot H_t \]

Error base process:
\[ dH_t = -\theta_t \cdot H_t \cdot dt + \sigma_t \cdot dW_t \]

Base process coefficients:
\[ \theta_t = c_\theta \cdot A(t) \]
\[ \sigma_t = c_\sigma \cdot (1 - A(t)) \]

Erroneous CF Model:
\[ \dot{x}(t) = v(t) \]
\[ \dot{v}(t) = a(\Delta \ddot{x}(t), \Delta \ddot{v}(t)) \]

\[ A(t) = "awareness" \]
Imperfect Driving 3

\[ A(t) = 1.0 \]

\[ A(t) = 0.1 \]