Lane-Changing Model in SUMO

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DLR

Introduction
Micro-Simulation Model Components

Model	Fixed	Configurable	Total SLOC
Car-following	140	90	**250**
Intersection	750	0	**750**
Lane-Changing	720	900	**1620**

SLOC = Source Lines of Code measured by the unix application `sloccount`

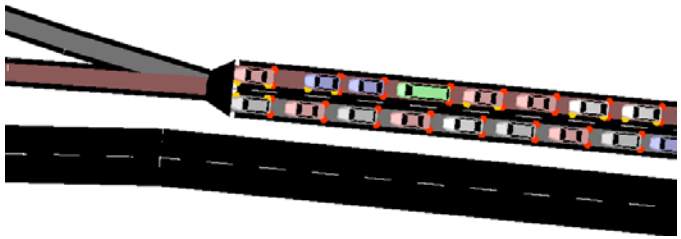
- `sumo/src: 183,000`
- `sumo/src/microsim: 25,600`

Outline

- Previous issues with lane-changing
- Model architecture
- Hierarchy of Lane-Changing Motivations
    - Strategic
    - Cooperative
    - Tactical
    - Regulatory
- TraCI
- Summary of Model Improvements
- Outlook

Previous Issues with lane-changing

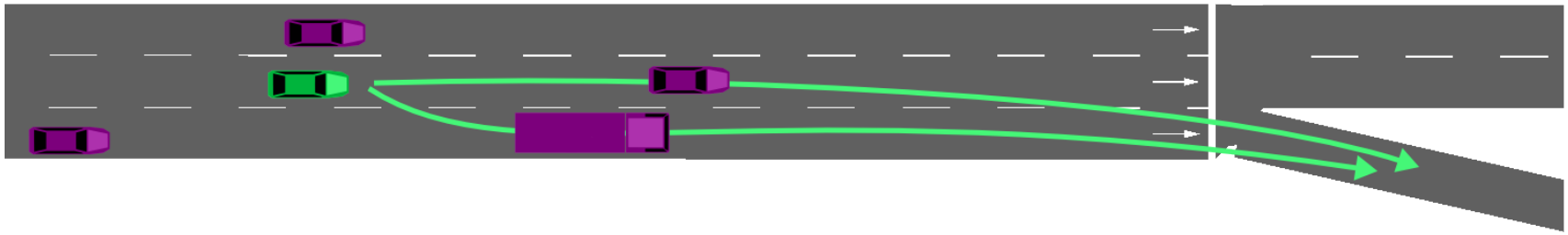
- unrealistic jamming where motorway splits (*A92* scenario).
- unrealistic jamming at motorway ramps (*Braunschweig* scenario).
- unrealistic jamming in front of intersections (*Braunschweig* scenario).
- low throughput in two-lane roundabout (*ACOSTA* scenario)



Model architecture

1. Compute strategically preferred lanes
2. Compute velocity considering safety and *lane-change speed request*
3. **Compute lane-change request**
4. **Compute *lane-change speed request*** or execute lane-change

   configurable: `laneChangeModel`



Hierarchy of Lane-Changing Motivations

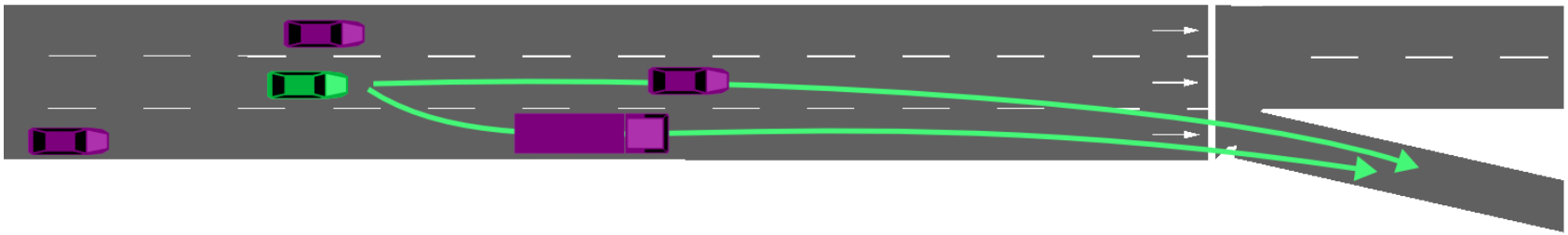
Priority	Lane-Change Motivation	Explanation
1	Strategic (urgent)	Follow the route
2	Cooperative	Help others follow their route
3	Tactical	Maintain desired speed
4	Keep Right	Follow regulation
5	Strategic (non-urgent)	Reduce future urgency

Strategic Lane-Changing

- **Evaluate lanes for strategic usefulness**
- Determine urgency (distance, number of lane-changes, traffic level)

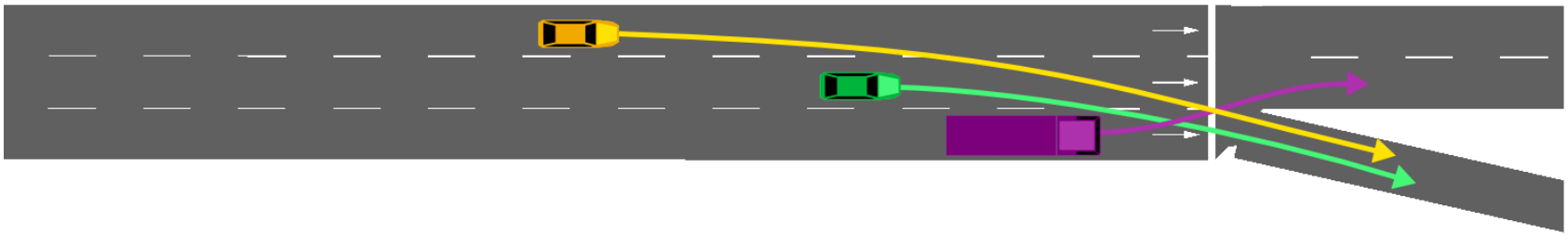
Strategic Lane-Changing (2)

- Evaluate lanes for strategic usefulness
- Determine urgency (distance, number of lane-changes, traffic level)
- **Compute necessary speed adjustment to clear blocking vehicles in front and behind**
  - **Overtake or follow the blocker**



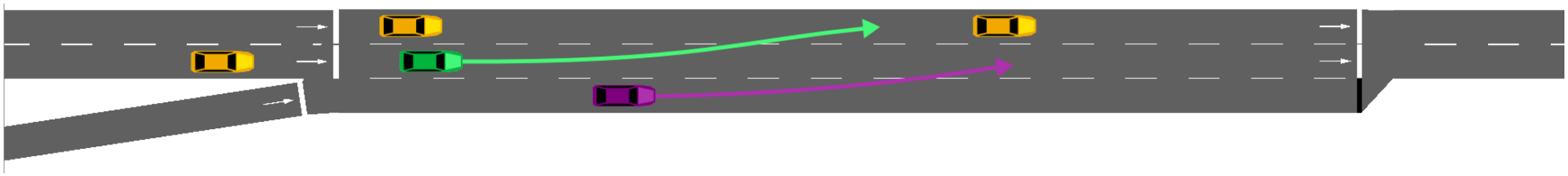
Strategic Lane-Changing (3)

- Evaluate lanes for strategic usefulness
- Determine urgency (distance, number of lane-changes, traffic level)
- Compute necessary speed adjustment to clear blocking vehicles in front and behind
    - Overtake or follow the blocker
- **Prevent Deadlock with counter-changing vehicles**
    - **avoid moving to non-continuing lanes***



Cooperative Lane-Changing

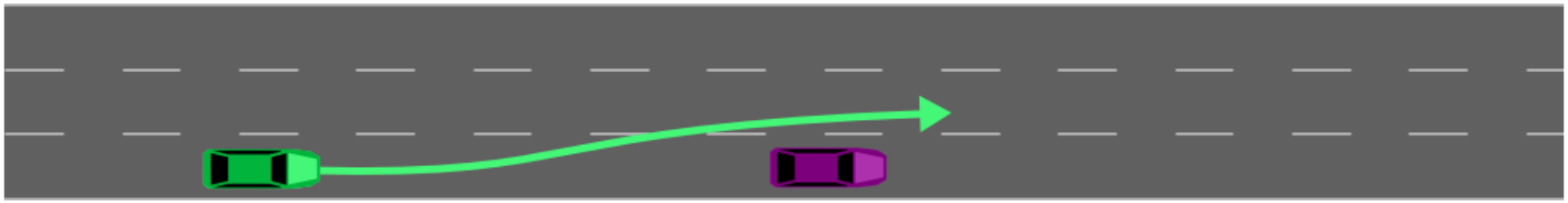
- Change to a different lane if
  - A vehicle in *front* wants to change
  - Is blocked by me
- Less speed adjustment to avoid disturbing motorway flow (not urgent for ego)
- Use the inside lane of a roundabout if possible



Tactical Lane-Changing

- Aggregate expected speed gain until threshold is reached
- Asymmetry between overtaking left and right (configurable*)

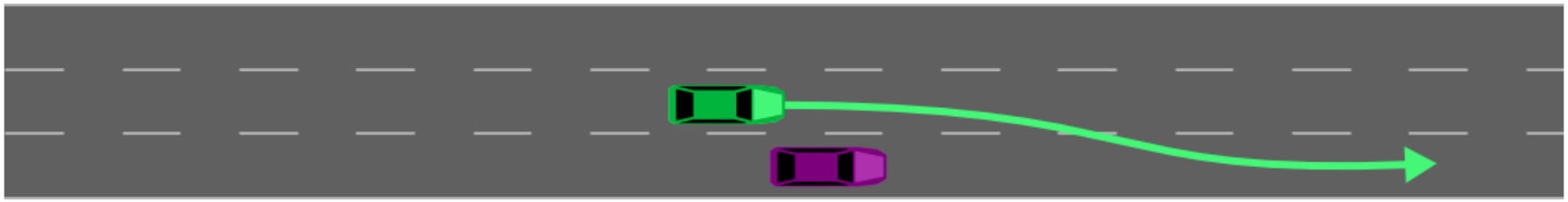
$$p' = p + \frac{v_{left} - vc_{urrent}}{v_{left}}$$



Regulatory Lane-Changing (Obligation to clear the Overtaking-Lane)

- Drive right unless overtaking (now or in the near future)
- Depends strongly on the desired speed of the ego vehicle
- Bias towards German motorway traffic

$$q' = q - \frac{t_{expected}\, v_{max}}{v_{desired}\, v_{current}\, T}$$



TraCI

- Request to move to / stay on a specified lane for the next x seconds
- Resolve conflicts via command *lane change mode 0xb6*
  - between TraCI-request and `laneChangeModel` request
  - Between TraCI-request and car-following constraints

`0b10010101001`

`00`: Ignore other drivers
`01`: Avoid immediate collision
`10`: Respect safety, adapt speed
`11`: Respect safety

`00`: no keep-right changes
`01`00: no tactical changes
`10`01`00`: no cooperative changes
`10`01`00`: no strategic changes
`10`01: `01`: unconflicted strategic changes
`10`: all strategic changes

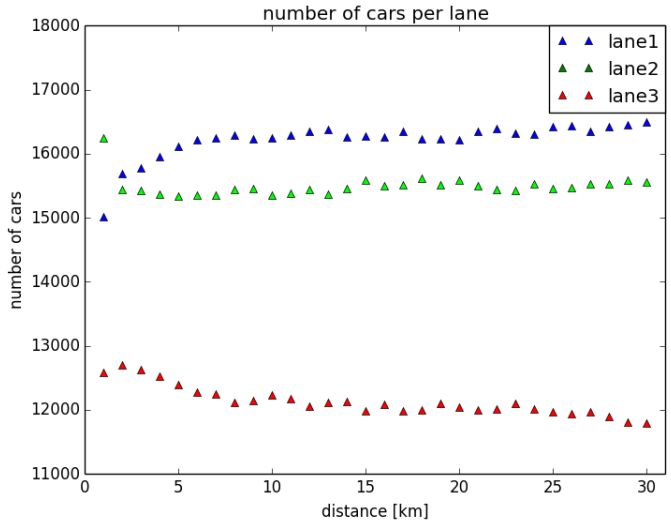
Summary of Model Improvements

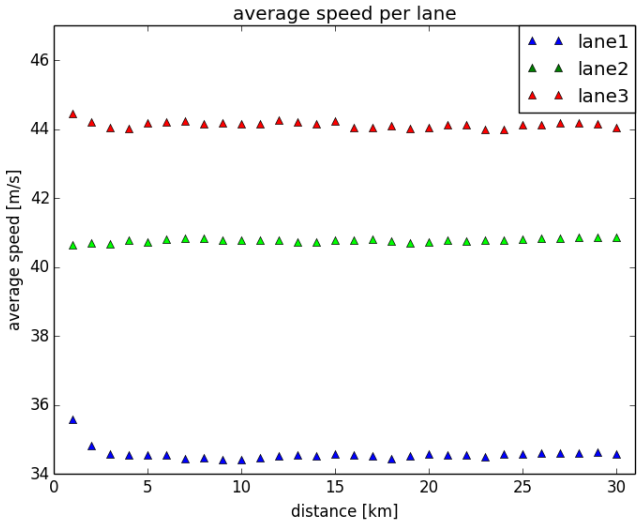
- better speed adjustments to fulfill change
- Better choices between overtaking and following blockers
- Less deadlocks in counter-lane-change situations
- No more flow brake-downs on motorway at busy on-ramps
- Better utilization of multi-lane roundabouts
- Better look-ahead for regulatory lane changing
- Fine grained control via TraCI

- **Major reduction in invalid stopping and jamming in all test scenarios**

Outlook

- Calibration / Validation using real-world data – expose parameters
- Consider urgency of cooperative and tactical lane-changes
- Improve overtaking across multiple lanes
- Clear the overtaking lane for faster followers





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