

Safe but not Overly-cautious AD Vehicles navigation in Complex Scenarios with HD Maps

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2

Problem Description

Autonomous vehicles (AD) navigation in urban environments is challenging because of manually driven (MD) vehicles

- Intentions of MD vehicles are hard to predict and understand
- Limited information about MD vehicles (no V2V)

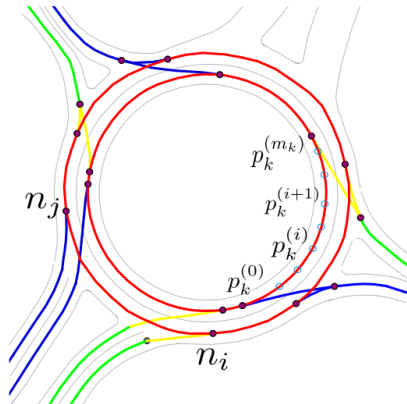
Roundabout navigation represents a challenging AD scenario

- Insertion maneuver is similar to road merging
- Ring has the right of way
- Traffic is highly irregular in the ring (lane changes)



Roundabout topology and HD maps

- HD map represented as a set of polylines (Links and nodes)
- Zones repartition for different navigation tasks



Insertion Maneuver

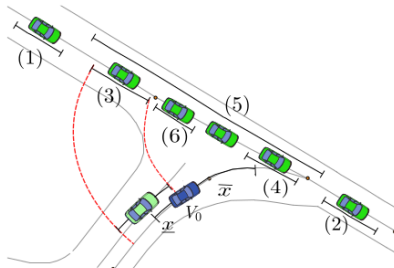
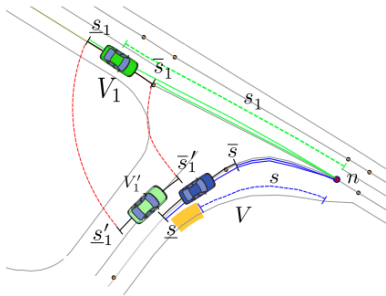
An AD vehicle :

- has to keep a safe inter-distance w.r.t. the vehicle ahead
- has to respect the traffic rules (vehicles inside the roundabout have the right of way)
- should avoid stopping on the carriageway as much as possible

Strategy

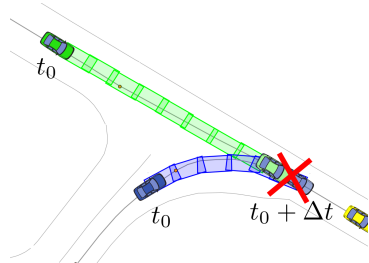
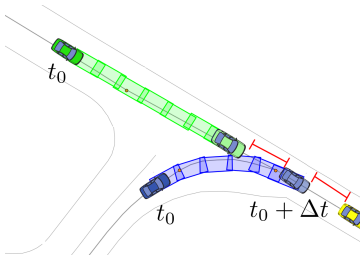
The AD vehicle needs to take into account the navigation throughout the yellow zone directly in the green zone to find the best gap to fit in the flow of vehicles.

Intervals-based Virtual Platooning



- MD information represented as $V_i = [s_i, \bar{s}_i, v_i, P_i]$
- $[s_i, \bar{s}_i]$ represents the vehicle occupancy
- Virtual curvilinear inter-distance w.r.t. the first common node

Gap Fitting



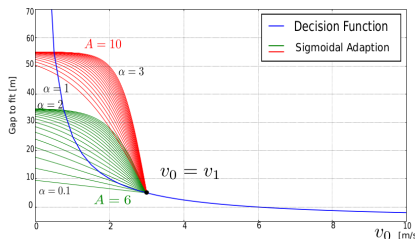
- Prediction over the merging zone horizon
- Prediction along HD map polylines
- Gap fitting or safe stop

Formalism

- Gap fitting criterion : $d_{0,1}^*(t_0) - d_{\text{safe}} + \left(1 - \frac{v_1}{v_0}\right) l \geq 0$ if $v_0 < v_1$
- Singularity at $v_0 = 0$

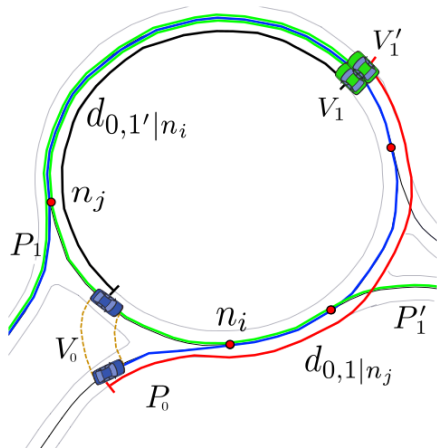
$$\begin{cases} d_{0,1}^*(t_0) \geq d_{\text{safe}} & \text{if } v_0 > v_1, \\ d_{0,1}^*(t_0) \geq d_{\text{safe}} - \hat{h}(v_0)l & \text{else.} \end{cases}$$

$$\text{With } \hat{h}(v_0) = A \left(\frac{1}{1 + e^{-\alpha(v_0 - v_1)}} - \frac{1}{2} \right)$$



Virtual Instances

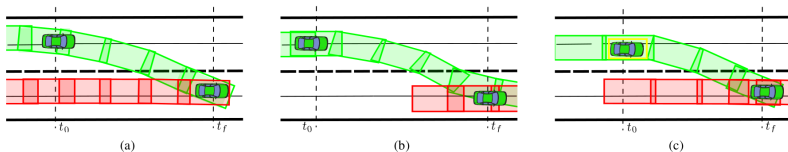
- Uncertain intention prediction (vehicle path and lane change)
- Manage pathological cases in roundabouts



Multi-lane Roundabout Handling

Issue

Lane changes and nudging behaviors are hard to predict



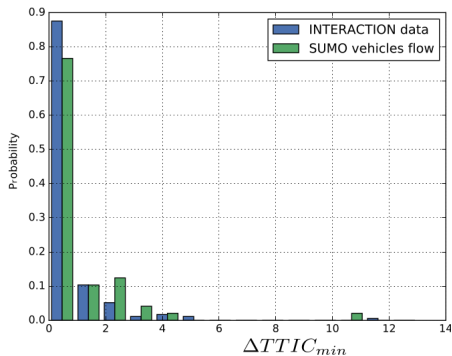
- All the lanes always occupied (a)
- Lane occupancy when lane change is effectuated (b)
- Lane occupancy when lane change intention is detected (c)

Simulated Vehicles Flow

Goal

Generate a simulated vehicle flow with a highly interactive and adversarial behavior

- SUMO simulator
- INTERACTION traffic flow data
- $\Delta TTIC_{min}$ metric



Simulation Results

Simulation on the "Guy Dénielou" roundabout with random high density vehicle flows

- Single-lane roundabout

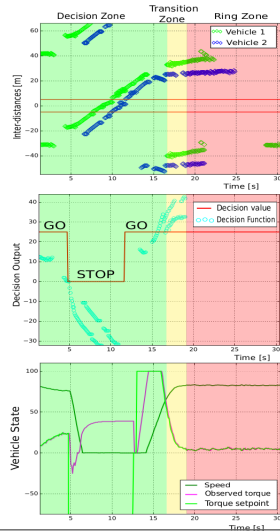
	50	75	100	125
Crossing Time (s)	5.60 (+1.3)	7.32 (+1.7)	10.05 (+2.39)	15.26 (+3.63)
Number of Insertions	24	21	18	16

- Multi-lane roundabout

Method	behind	Ahead	Cross time	Wait time
Two lanes occupancy	0%	0%	23.3s	14.46s
Only one lane occupancy	30%	29%	8.6s	4.7s
Intention detection	0%	4%	16.4s	7.79s

Experimental Results

- Seville experimental circuit
- On-board perception system



Conclusion

- Safety must be ensured during complex zones navigation
- Simulation of a realistic traffic flow is challenging
- To improve flowability, a lane change intention predictor is required