Conflict Analysis for Cooperative Merging Using V2X Communication

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Background & Motivation

- Merging remains one of the challenging traffic scenarios for both human-driven and automated vehicles [1]
- Due to human driver’s unpredictable behavior, conflict can often occur
- V2X communication is a promising way to prevent conflict [2] connected human-driven vehicles (CHVs) connected automated vehicles (CAVs)

- Optimization based methods [3]
  - Minimize overlap of vehicle positions in merging zone
  - Constraints formulated with goal of avoiding collisions
  - We consider the scenario where CAV interacts with CHV

- Reachability based methods [4]
  - In state space, numerically find the set where collision is unavoidable
  - Intervene once trajectory hits boundary
  - We want the CAV to make a decision much earlier

Merge scenario

- Two vehicles should not appear in the conflict zone at the same time
- Vehicle 1 shares position & velocity information via V2X (e.g., basic safety message)
- Make decision and design control algorithm for vehicle 2

Dynamical models of vehicles (longitudinal)

Vehicle 1
\[ r_1 = -r_1, \]
\[ v_1 = sat(v_1), \]
\[ a_1 = -a_{max}. \]

Vehicle 2
\[ r_2 = -r_2, \]
\[ v_2 = sat(v_2). \]

Conflict scenario

Conflict Analysis

- Can Veh 2 merge ahead of or behind Veh 1?
- Optimization based methods
- Reachability based methods

Communication range & Controller

Communication range: Veh 2 has to receive one packet from veh 1 when veh 1 is at least \( r_1^2 \) away from the conflict zone (e.g., \( r_1^2 = 124 \) [m])

Decision making

\[ \text{Decision} = \begin{cases} 
\text{Merge ahead}, & \text{if } x(0) \in A_P, \\
\text{Merge behind}, & \text{otherwise}. 
\end{cases} \]

Controller

\[ u_2(t) = -\kappa \cdot \dot{x}, \]
where \( \kappa = \kappa_{\text{max}} \)

Packet update rate

Time to merge 12.42 s 10.80 s 10.57 s

Conclusion & Future work

- Proposed conflict analysis and applied to a merge scenario
- Designed decision making rule and controller
- Demonstrated that V2X can contribute to a conflict-free merge
- Will scale up conflict analysis for larger number of vehicles