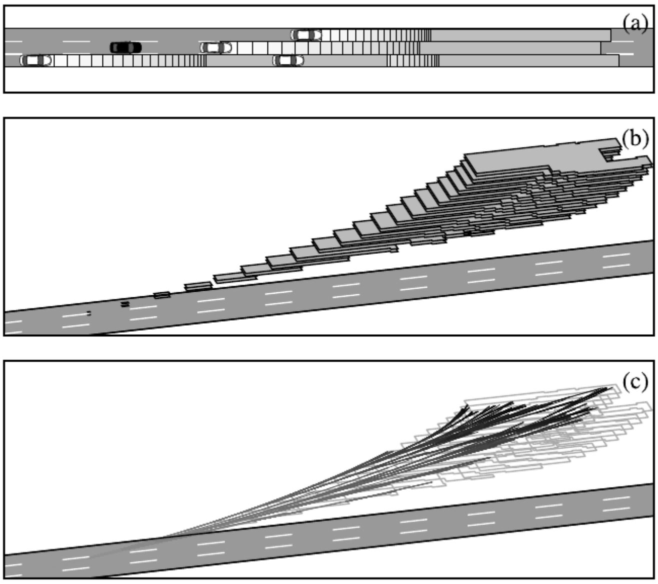
Specification-compliant Maneuver Planning via Reachable Sets

Background

Highly automated vehicles (AVs) promise increased road safety compared with human-driven ones. To safely and effectively participate in road traffic, AVs should explicitly consider compliance with traffic and handcrafted rules. Compliance with the former exempts manufacturers from potential liability claims in case an accident happens, whereas the latter contribute to finding motion plans that meet specific requirements. Determining a drivable trajectory that satisfies a desired discrete specification involves reasoning with both discrete and continuous states of AV, which poses computational challenges originating from (a) vehicle dynamics and collision avoidance, (b) discrete specifications, and (c) interwoven dependencies between continuous trajectories and discrete constraints. Planning on the discrete level may output plans that meet the specifications but do not satisfy dynamic constraints; similarly, motion planning methods may generate collision-free and dynamically feasible trajectories that violate the specifications.

Description

The goal of this thesis is to generate (optimal) specification-compliant maneuvers via semantic reachable sets of a considered ego vehicle. The reachable sets [1] are sets of collision-free states that are reachable for a vehicle over time. The semantically labeled reachable sets [2] additionally carry sets of labels (predicates present in traffic rules or handcrafted specifications that evaluate to true) whose so-called robustness values (how far is a signal from satisfying/violating a specification) [3, 4] can be calculated. After obtaining a reachability graph and computing the robustness values of each node in the graph, one can use a graph-search algorithm (e.g. A*) to generate (optimal) maneuvers that comply to the desired traffic or handcrafted rules.



Drivable area (projection of reachable sets onto the position domain) over time [1].

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Research project:
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Type:
Bachelor

Research area:
Reachability Analysis, Temporal Logic, Traffic Rule

Programming language:
mainly Python, could involve some C++

Required skills:
Good programming skills, highly motivated, self-organized

Language:
English

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Rule	Law reference	MTL formula
R_G1	§ 4(1) StVO; § 13(5) VCoRT	$\mathrm{G}\big(\mathrm{in\_same\_lane}(x_{\mathrm{ego}}, x_{\mathrm{o}}) \wedge \mathrm{in\_front\_of}(x_{\mathrm{ego}}, x_{\mathrm{o}}) \wedge \neg \mathrm{O}_{[0,t_c]}\big(\mathrm{cut\_in}(x_{\mathrm{o}}, x_{\mathrm{ego}}) \wedge \mathrm{P}(\neg\, \mathrm{cut\_in}(x_{\mathrm{o}}, x_{\mathrm{ego}}))\big) \implies \mathrm{keeps\_safe\_distance\_prec}(x_{\mathrm{ego}}, x_{\mathrm{o}})\big)$
R_G2	§ 4(1) StVO; § 17(1) VCoRT; [32] StVO § 4 Rn. 15-16	$\mathrm{G}\big(\neg\, \mathrm{unnecessary\_braking}(x_{\mathrm{ego}}, \mathcal{X}_{\neg\mathrm{ego}})\big)$
R_G3	§ 3(1), § 3(3), § 18(1), § 18(5), § 18(6) StVO; traffic sign 274	$\mathrm{G}\big(\mathrm{keeps\_lane\_speed\_limit}(x_{\mathrm{ego}}) \wedge \mathrm{keeps\_fov\_speed\_limit}(x_{\mathrm{ego}}) \wedge \mathrm{keeps\_type\_speed\_limit}(x_{\mathrm{ego}}) \wedge \mathrm{keeps\_braking\_speed\_limit}(x_{\mathrm{ego}})\big)$
R_G4	§ 1(2), § 3(2) StVO; [32] StVO § 3 Rn. 48	$\mathrm{G}\big(\neg\, \mathrm{slow\_leading\_vehicle}(x_{\mathrm{ego}}, \mathcal{X}_{\neg\mathrm{ego}}) \implies \mathrm{preserves\_flow}(x_{\mathrm{ego}})\big)$
R_I1	§ 12(1), § 18(8) StVO; [32] StVO § 18 Rn. 22	$\mathrm{G}\Big(\neg\big(\mathrm{in\_congestion}(x_{\mathrm{ego}}, \mathcal{X}_{\neg\mathrm{ego}}) \vee \mathrm{exist\_standing\_leading\_vehicle}(x_{\mathrm{ego}}, \mathcal{X}_{\neg\mathrm{ego}})\big) \implies \neg\, \mathrm{in\_standstill}(x_{\mathrm{ego}})\Big)$

A selection of formalized traffic rules.[5].

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Tasks

- Familiarize yourself with the CommonRoad platform.
- Familiarize yourself with semantic reachable sets computation.
- Calculate the robustness values for reachable sets from a selection of predicates and traffic rules.
- Perform (graph) search algorithms over reachability graph to generate (optimal) specification-compliant maneuvers.
- Document your code and other related materials.
- Write the final thesis.

References

[1] S. Söntges and M. Althoff, "Computing the drivable area of autonomous road vehicles in dynamic road scenes," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 6, pp. 1855–1866, 2018.

[2] E. Irani Liu and M. Althoff, "Computing specification-compliant reachable sets for motion planning of automated vehicles," in *Proceeding of the IEEE Intelligent Vehicles Symposium*, 2021, pp. 1–8.

[3] Rtamt. https://github.com/nickovic/rtamt.

[4] D. Ničković and T. Yamaguchi, "Rtamt: Online robustness monitors from stl," in *International Symposium on Automated Technology for Verification and Analysis*. Springer, 2020, pp. 564–571.

[5] S. Maierhofer, A.-K. Rettinger, E. C. Mayer, and M. Althoff, "Formalization of interstate traffic rules in temporal logic," in *2020 IEEE Intelligent Vehicles Symposium (IV)*. IEEE, pp. 752–759.