ISCAS 中国科学院软件研究所学术年会'2022
暨计算机科学国家重点实验室开放周
学术论文

ComOpT：基于组合与优化方法的自动驾驶系统测试工具

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论文题目： ComOpT： COMbination and Optimization for Testing autonomous driving systems

学术会议： International Conference on Robotics and Automation

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Abstract

ComOpT is an open-source research tool for coverage-driven testing of autonomous driving systems, focusing on planning and control. Starting with (i) a meta-model characterizing discrete conditions to be considered and (ii) constraints specifying the impossibility of certain combinations, ComOpT first generates constraint-feasible abstract scenarios while maximally increasing the coverage of k-way combinatorial testing. Each abstract scenario can be viewed as a conceptual equivalence class, which is then instantiated into multiple concrete scenarios by (1) randomly picking one local map that fulfills the specified geographical condition, and (2) assigning all actors accordingly with parameters within the range. Finally, ComOpT evaluates each concrete scenario against a set of KPIs and performs local scenario variation via spawning a new agent that might lead to a collision at designated points. We use ComOpT to test the Apollo 6 autonomous driving software stack. ComOpT can generate highly diversified scenarios with limited test budgets while uncovering problematic situations such as inabilities to make simple right turns, uncomfortable accelerations, and dangerous driving patterns. ComOpT participated in the 2021 IEEE AI Autonomous Vehicle Testing Challenge and won first place among more than 110 contending teams.

Features

Automatic tool chain
Scenario generation, simulation, evaluation and script generation

Automatic coverage maximization
Constraint-feasible with k-way combinatorial testing

Scenario perturbation with agent spawning
Behavior understanding and fine-tuning the introduced agents

High diversity in problem shooting
Various metrics for scenario evaluation

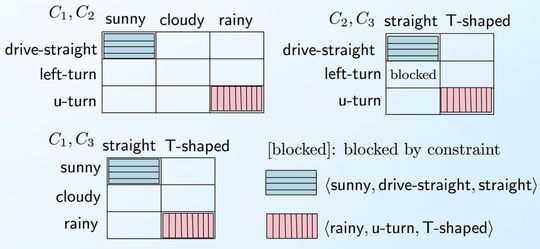
Abstract Scenario Generation

Categories (simplified):

- weather ∈ { sunny, rainy, cloudy }
- road ∈ { straight, T-way }
- ego-action ∈ { drive-straight, left-turn, u-turn }

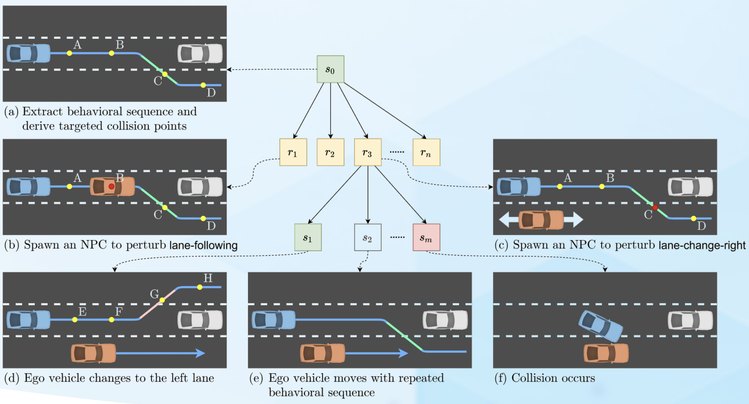
Feasibility constraints:

- road.straight → ¬ ego-action.left-turn



Scenario Variation (Agent Spawning)

- Introduce new agents into scenarios to challenge the ego vehicle.
- Resolve the problem into multiple search tasks based on the behavioral patterns and trace of the ego vehicle.
- A meta-level strategy to manage the ordering of the search.



(a) Extract behavioral sequence and derive targeted collision points

(b) Spawn an NPC to perturb lane-following

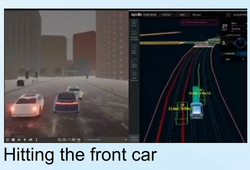
(c) Spawn an NPC to perturb lane-change-right

(d) Ego vehicle changes to the left lane

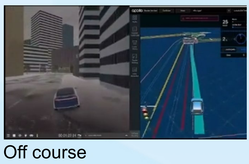
(e) Ego vehicle moves with repeated behavioral sequence

(f) Collision occurs

Problematic Scenarios



Hitting the front car



Off course

Driving into opposite line