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A criticality-Guided Sampling Strategy for test scenarios reduction for driving automation validation

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Introduction

Motivation

- Need to regularly test new functionalities on CAV and set up pre-certification process, including test phases.
- Two Type of *scenario-based reduction* [1]:
 - Testing-based processing*: Sampling approach
 - Falsification-based process*: Find critical scenario

Objectif and Innovative

- This paper develops a testing-based process implemented with a preliminary computation of criticality indicators. The main focus lies in the introduction of the experimental protocol to select the functional scenarios to evaluate. Especially, a sampling guided by precomputed criticality levels is used to design the experimental plan
- We get interested in a **scenario-based** developed in former works [1]. The current work add two supplementary steps to design the experimental plan:
 - Step 5**: Clustering of S_f by semantic similarity and criticality differences
 - Step 6**: Cluster space reduction in terms of S_f criticality and attributes coverages

Conclusion

- Presentation of an aggregated and generic methodology in 6 steps which aims at reducing the number of functional scenarios to be explored for the certification of CAV systems
- We compared the several approaches and illustrated this with an abacus

Bibliography

- [1] Riedmaier, S., T. Ponn, D. Ludwig, B. Schick, and F. Diermeyer, Survey on Scenario Based Safety Assessment of Automated Vehicles. IEEE Access, Vol. 8, 2020, pp. 87456-87477, conference Name: IEEE Access.
- [2] Blache, H., P.-A. Laharotte, and N.-E. El Fouzi, How to Rationalized the Sampling of Test-Scenarios in Automated Driving Based on Criticality Metrics? In 2023 International15 Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS),16 IEEE, 2023.

Methodology

Step 1 to 4

Functional Scenario Definition and Metrics

$$\forall i \in [1, q] S_{f_i}^{ontology} = (\beta_{w_1} \beta_{w_2} \dots \beta_{w_n}) \forall j [1, n] \beta_{w_n} \in \{0,1\}$$

$$\forall i \in [1, q] S_{f_i}^{ontology} = (P_1 P_2 \dots P_n) \forall j [1, n] P_j = \frac{1}{j}$$

Functional Scenario Qualification

$$\forall i \in [1, q] S_{f_i}^{qualification} = 100 * \frac{\sum_i^{nb_i} d^{criticality}(S_{c_{nb_i}} < 1.5s)}{\sum_i^{nb_i} d^{criticality}(S_{c_{nb_i}})}$$

Step 5

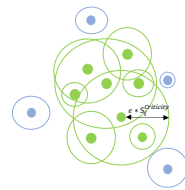
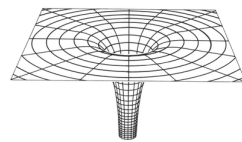
- Clustering algorithms estimates distance between functional scenarios using semantic metrics and adjusts space based on criticality levels. We compare two approaches based on two distinct algorithms

Weighted-K-means

$$\forall i \in [1, q], Weight_{S_{f_i}} = \frac{1}{S_{f_i}^{qualification}}$$

DBSCAN-RNC

$$\forall i \in [1, q], R = \epsilon * S_{f_i}^{qualification}$$



Step 6

Criticality coverage

- Identify the most critical scenarios
- Select as many as possible scenarios with high criticality levels

Attributes/Semantic Coverage

Distance to the cluster centroid

$$Dist_{kernel} = \| \beta_i - \beta_{kernel} \|^2$$

Distance intra-cluster

$$Dist_{intra} = \| \beta_i - \beta_j \|^2 / N$$

