A Graph-based Framework for Coverage Analysis in Autonomous Driving

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1 Abstract

2 Introduction

- In autonomous driving, coverage analysis is a crucial step to ensure the safety and reliability of the system.
- In most situations, coverage arguments are collected either per coverage factor, or maybe up to 2 or 3 factor interactions.
- See for example [11] for an production grade implementation of state of the art coverage analysis.
- In contrast to existing approaches, this paper proposes a graph-based framework for coverage analysis.
- There are already other graph-based approaches for analysing and representing traffic scenes, see for example [5].
- However, the work in that paper is not specifically focused on coverage analysis.
- Hence in this paper, graph based traffic scene representations are utilized for coverage analysis.
- This paper is structured as follows:
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3 exsting coverage and analysis approaches

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4 Defining a traffic scene graph

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4.1 time based graph representations

5 Analysing a traffic scene with agraph

- Having defined a graph-based traffic scene representation, we can now analyse the coverage of the system.
- Two methodologies are proposed for this purpose:
- One is to define archetypes of traffice scenes, and to compare graphs from observed traffic scenes to these archetypes.
- The second one is to translate graphs to graph embeddings, and then to compare the embeddings of different sets of traffic scenes.

5.1 Create subgraphs for coverage analysis

- There is a lot of knowledge in the literature on how to define archetypes of traffic scenes.
- Once an archetype is defined, a special property of graphs can be used.

- Two graphs are isomorphic if they have the same structure, regardless of the node and edge labels.
- As the archetypes are not necessarily are involving a lot of actors, these are more like subsets of actual traffic scenes.
- A very simple example might be 2 vehicles on the same lane, driving in the same direction and another vehicle driving on a neighboring lane.
- This situation can be represented by a graph with 3 nodes and 2 edges.
- In most real traffic situations however, there will be additional actors present, so that we are not searching for isomorphic graphs, but rather want to check if any subgraph of G is isomorphic to the archetype graph A.
- This is an example of a subgraph isomorphism problem.
- While this problem is NP-hard, the graphs considered here are rather small, so the computational time is reasonable.
- One such algorithm is the VF2 algorithm, which is implemented in the NetworkX library (see [7]).
- The strategy we are then applying is the following:
- 1. Define a set of subgraphs S that are considered to be archetypes.
  2. Define which node and edge attributes are considered for the isomorphism check.
  3. Create an empty dataframe C with a column for each subgraph in S
  4. Define the set of traffice scenes (e.g. from Carla or Argoverse) defined as graphs G
  5. For each graph G, check if any subgraph of G is isomorphic to any subgraph in S and note the result in a new row in table C
- This strategy can be described to some degree as a bottom up approach: Starting from a detail level, individual situations are defined.
- Then going upwards to different datasets, it is checked, if the archetype is present.
- Also, follow up analysis of the created coverage dataframe can be performed. For example,
- - The distribution of numeric attributes like speed and and distance to other actors can be visualized for the subset of all traffic scenes which are subgraph isomorphic to an archetype.
  - It can be cross tabulated, which combinations of archetypes are jointly present in a traffic scene.

- Pass Fail rates or other AV performance metrics can be calculated for the subset of all traffic scenes which are subgraph isomorphic to an archetype.

5.2 graph embeddings for coverage analysis

- One often utilized strategy in machine learning is to translate raw data like images or text into an embedding space in order to be

6 Application

6.1 Argoverse 2.0

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6.2 Carla

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7 Summary

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