

# A Graph-based Framework for Coverage Analysis in Autonomous Driving

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September 24, 2025

## 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:
  - In the first section, xxx

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### 3 existing 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 a graph

- 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 traffic 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 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 traffic 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 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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