A Methodology for Model-Based Validation of Autonomous Vehicle Systems

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***Abstract*— The deployment of autonomous vehicles requires safety assurance and performance guarantees of the developed system. However, this is complex due to the number of scenario variations and uncertainty associated with the operating environment. To alleviate this challenge, we propose a model-based validation methodology that relies on a functional hierarchy for the breakdown and simplification of the system navigation functions, and the Backtracking Process Algorithm to identify, trace, and probabilistically quantify risk significant event sequences (scenarios) that lead to Top Events of interest (such as requirement violations). This methodology is demonstrated on a scenario with an occluded pedestrian crossing the road. We are able to identify risks associated with the actor classification problem and sudden changes in behavior of the pedestrian.**

I. Introduction

Before the widespread use of autonomous vehicles (AVs) can be possible, it is of vital importance to solve the open problem of ensuring their safe and fault-free operation. The nature of the emerging AV technologies presents huge unprecedented challenges when it comes to their standardization and certification. These challenges can be mainly summarized in two different categories. The first challenge lies in the ability to impose safety requirements on systems. The second and more significant challenge lies in the ability to comprehensively test the system and provide assurance with an adequate level of confidence. These two challenges are directly relevant to the testing aspect of autonomous system validation and verification (V&V). Verification involves the first challenge and part of the second. The main objective of it is to verify that all the safety-by-design requirements are met. Validation is mainly related to the second challenge. It involves putting the verified system to the test in scenarios and situations the system is likely to encounter.

Traditionally, statistical approaches using distance-based methods have been most commonly used for addressing the second challenge. However, these methods are unfeasible due to the vast amount of testing required to accumulate the data needed for the construction of statistical arguments. Scenario-based approaches for V&V have been proposed as an alternative to statistical ones for vehicles with high levels of autonomy. The main objective of scenario-based testing is the identification of critical or edge-case scenarios that can be reproduced in both simulation environment and in the test fields. Such a solution would significantly decrease the amount of time and resources spent towards field testing.

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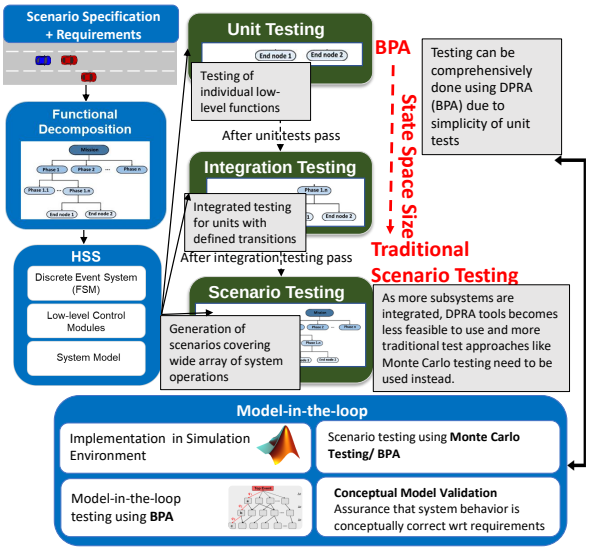

Fig. 1: Block Diagram of the Proposed Model-Based Testing Methodology

This motivated efforts over the past few years towards finding comprehensive approaches and frameworks for the testing and V&V of L3 to L5 autonomous systems. Most of these efforts were guided by industry and government institutes. Several write-ups have emerged as key documents that are guiding the path towards V&V of autonomous systems.

II. Model-Based Methodology for System Testing

A. The Model-Based Testing Methodology

The document by [13] was funded by the United States Department of Transportation (DoT) with the objective of developing an example of a preliminary test framework for L3 to L5 automated driving systems (ADSs) that are being developed. Safety First for Automated Driving [2] is an industry led effort for the development of industry-wide definitions of safety. The document [10] was produced as part of a European initiative to enable the validation of highly automated safe and secure systems. PEGASUS [11] is a project which adopts a scenario-based approach for V&V. It is promoted by the German Federal Ministry for Economic Affairs and Energy (BMWi) and involved numerous partners from industry. UL4600 [6], published by Edge Case Research, is a comprehensive safety standard for autonomous products. A collaboration between Edge Case Research and Carnegie Mellon was also done to discuss the