ArchitectECA2030

SC 4 Demo 4.3 Key Card

Virtual Verification & Validation Framework

Main aim	
Verification and validation are important to estimate the residual risk. Our demonstrator aims to make this process faster and more reliable, therefore, decreasing the residual risk by increasing the test coverage of monitoring devices and ADAS functions. *The demonstrator is a virtual framework in which verification and validation methods for monitoring devices and advanced driver assistant systems / automated driving (ADAS/AD) controllers can be tested without risks to the environment or system. In this testing framework, different approaches for verification and validation can be used and qualitatively compared to each other. Furthermore, the framework should be reusable for different monitoring devices and ADAS/AD controllers.*	
Partners	*AVL, SBA, TUG*
ECS value chain	*Tier 1*

State-of-the-art	**Beyond SotA / Innovation**	**Targeted TRL**
• *System testing in virtual environments is done, although seldom. A problem is the huge parameter space of such tests.* • *Only a static analysis of output signals is performed.* • *Using CT*	• *Application of developed combinatorial testing methods to reduce the number of needed test cases to test an ADAS/AD system or SAE L3+ car* • *Novel system scenario generator to create complex scenarios from simple input parameters.* • *Verification and validation are important to estimate the residual risk. Our demonstrator aims to make this process faster and more reliable, therefore, decreasing the residual risk by increasing the test coverage of monitoring devices and ADAS functions*	• TRL 3 • TRL 4 • TRL 5

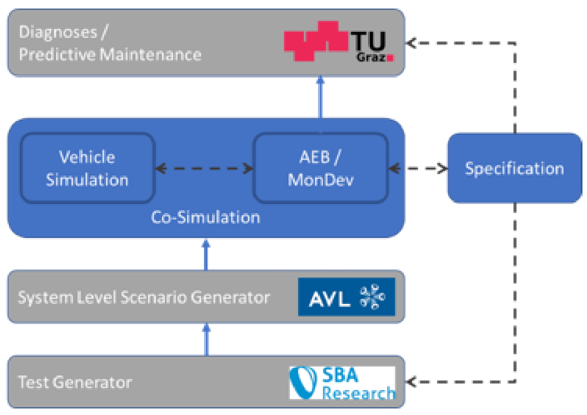
Link to project objectives

Objective	***Addressed (Y/N)***	***How***
O1 – Continuous robust design optimization for each part in the ECS value chain	*Y*	*By employing the framework more robust SAE L3+ cars can be developed.*
O2 – Framework for safety validation of ECS value chain	*Y*	*Our demonstrator directly contributes to this objective by proposing a potential framework for safety validation of SAE L3+ cars.*
O3 – Identification & management of residual risks over the entire ECS value chain	*Y*	*Statistical analysis from the simulations can be used to estimate the residual risk of the system.*
O4 – End-user acceptance by trustworthy ECS value chain	*N*	
O5 – Zero emissions, zero crashes, zero congestions by ECA2030-car	*N*	

Joint demonstrator (JDEM)			**Linked supply chains (Y/N)**			**Considered MonDev layers (Y/N)**	
DEM 4.3							
				SC1	N	**System (S)**	N
SS				**SC2**	Y	***Subsystem (SS)***	Y
				SC3	N	***Component (C)***	N
				SC4	Y	***Subcomponent (SC)***	N

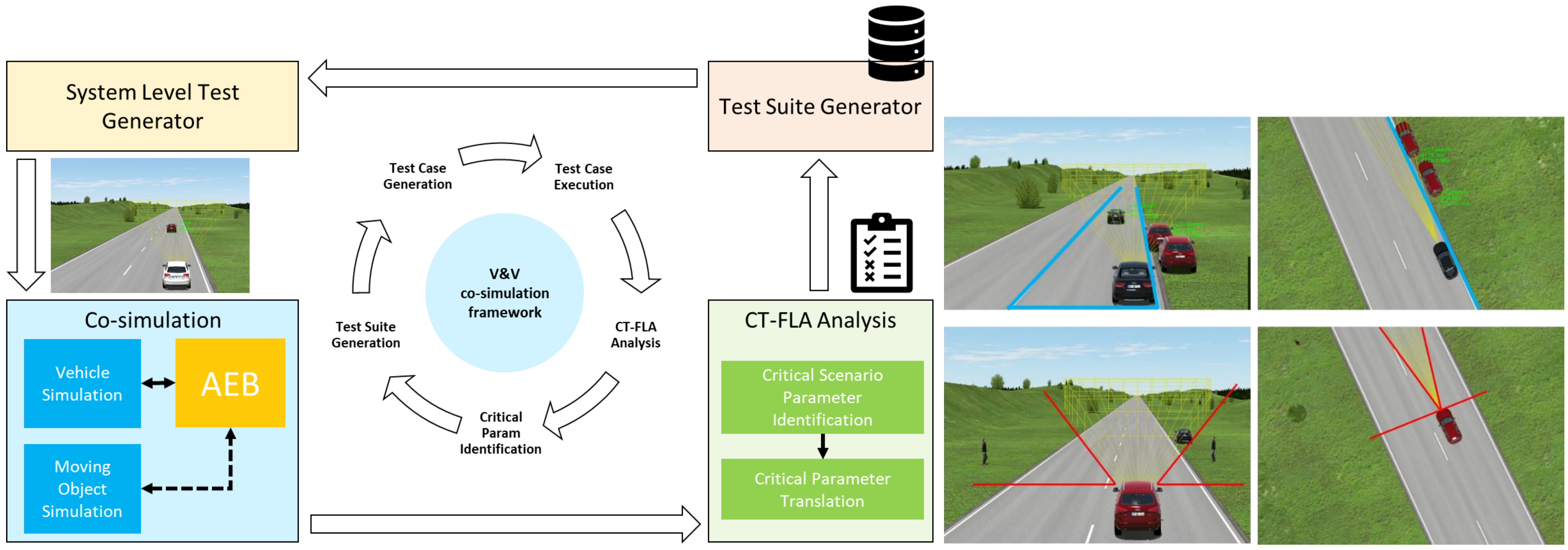
Setup

- *AVL's system scenario generator will create complex scenarios from simple input parameters, together with SBA's approach this will decrease the number of needed test cases further.*
- *SBA will use novel testing methods to reduce the number of needed test cases to test an ADAS/AD system or SAE L3+ car.*
- *TUG will use diagnosis to monitor the behavior of the system under test and give detailed information about the test execution. This can be used as feedback for SBA's and AVL's approach.*



Benchmark scenario/mission/etc.

Simulation of AEB function in framework and CT method application based on simulation observations.

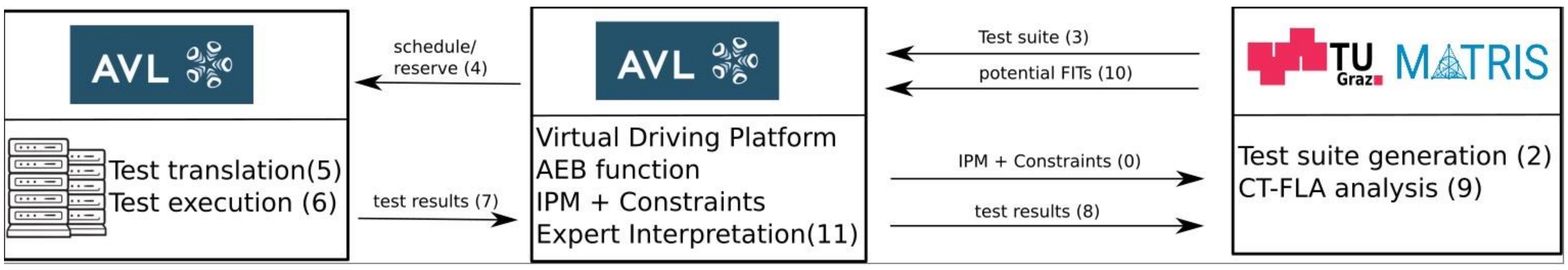


pav. 1: Overall framework showing the complete processing pipline starting with the test case generation, followed by the V&V co-simulation framework for simulting the provided test cases. Next a CT-FLA analysis is perofrmed to identify critical parameters and translate the gathered results in a format to enahnce the test suite generator. The right picture illustrates critical areas which were identified based on the CT-FLA analysis. The areas showing the limitations of the sensor causing crashes with pedestrians or vehicles in identified scenarios.

KPIs (related to requirements)	Baseline
Input/Output requirements • *Monitoring functionality must have inputs that can be manipulated and outputs that can be observed. The inputs/outputs have to match the predefined inputs/outputs of the framework.* **Monitoring functionality must work independent of the environment** • *The monitoring device must not try to detect in which environment it is run.* **The input model must be a discrete model** • *It must be possible to represent the input model (operational domain of MonDev) as a discrete model.*	**Diagnosis robustness** • *Performance, robustness, and reliability must be specified for the diagnosis functionality. The diagnosis functionality must be real-time capable.* **Diagnosis Maintainability** • *The framework as well as the MonDev should be easily adaptable.* **Diagnosis scalability** • *The diagnosis functionality should be saleable, such that it can be used for different sizes for MonDevs.*

Evaluation

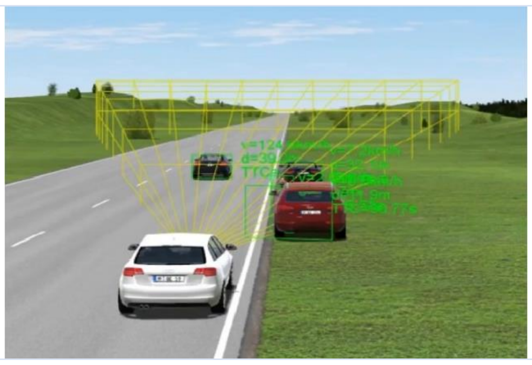
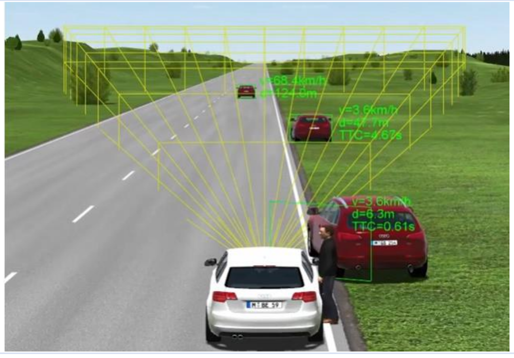
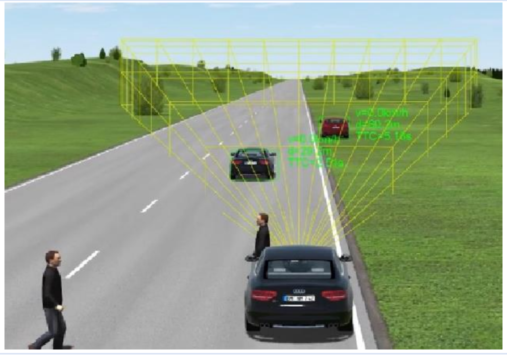
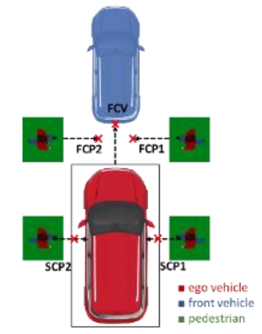
The evolution of the developed methods and algorithms is performed on the Co-Simulation framework including an ADAS/AD function, a AEB function and Monitoring Device for diagnosis. The executed test cases are generated by the developed CT method and compared to actual applied test case generators.



Highlights

- *A total number of **14097 crash scenarios** generated.*
- *Dedicated test suites for triggering crash-inducting t-way interactions achieve a **crash rate of up-to 87%***
- *With CT-FLA we were able to identify crash-inducting t-way interaction of length $t \geq 6$*
- *This 6-way interaction appears in millions of tests (6*10^26 when disregarding constraints)*
- *These millions of tests can be disregarded in further testing.*
- *Test suite generation with **high test coverage** and certification tests by respecting all constraints and executing strength 2 and 3.*
- *Test suite **quality increasing** by adding tests towards identifying crash-inducing parameter settings.*
- *V&V of AEB function with a **constraint-based test cases catalog** based on the gathered test suite.*
- *Provide important information for system **development phase**.*
- *Provide critical test cases for the actual AEB implementation and generate **unit tests**.*
- *Providing important information about potential implementation failures with root cause analysis in the development phase of an ADAS function.*
- *Detailed explainability of critical scenarios by consideration of all simulation framework parameters including their correlations.*
- *Revealing system under test issues, i.e., function (main target object selection), sensor technology (angle of view) and sensor mounting (uncovered areas).*
- *Generation of scenarios aligned with the target operational design domain (ODD).*
- *Test suite optimization by proactively excluding similar subsequent generated test cases.*
- *Crash flag characteristic analysis to trigger and evaluate specific crashes.*
- *Paper publication: L. Kampel, et al., "Applying CT-FLA for AEB Function Testing: A Virtual Driving Case Study," in 2023 IEEE International Conference on Software Testing, Verification and Validation Workshops (ICSTW), Dublin, Ireland, 2023 pp. 237-245. doi: 10.1109/ICSTW58534.2023.00049*

Process	Result	Benefits
Avoid *identified parameter and scenarios in further testing*	*Avoid redundant tests where the cause of the crash is already known*	*Significant reduction in number of required test case selection.*
Trigger *identified parameter and scenarios on purpose for exploring the crash scenario more closely*	*Scenario explainability*	*Important knowledge to support development and root cause analysis of unexpected behavior in the SUT.*
Learn *from identified parameter and scenarios for future development steps*	*Regression testing*	*Improve V&V process during development*

Impact

V&V based on novel CT testing methods applied on an AEB safety system of an ADAS vehicle and a monitoring device.

Used standards

- *ISO 26262*
- *SOTIF (ISO PAS 21448)*
- *ISO TR 4804*
- *IEEE P2846*
- *ISO/IEC TR 24028*
- *ISO / IEC 25010*
- *UL 4600*
- *ASAM OpenDrive®*
- *ASAM OpenScenario®*

Future standardization potentials

- *Not perceived yet*

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Demo Leader Contacts:
Company
Name, Surname, email.