Automated NCAP tests with ASAM OpenSCENARIO

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Abstract: Euro NCAP provides descriptions of collision scenarios to test active safety systems of vehicles such as AEB. To conduct these tests in simulation, the scenarios must be described in a machine-readable format. This application story sheds light on the capabilities of OpenSCENARIO XML and OpenDRIVE in that regard. As the Euro NCAP scenarios are widely used, Vector decided to contribute the implementation of these scenarios using the ASAM standards open source at https://github.com/vectorgrp/OSC-NCAP-scenarios.

1 Introduction

It is undisputed that the development and validation of complex ADAS functions require scenario-based testing as an essential component of the test strategy. Due to the high resource consumption of real-world test drives and the often late availability of technology carriers and prototypes in the development process, these test drives are increasingly conducted in a simulated manner. This process already begins in early development phases with model-based function design (MIL) continues through the implementation of functions as control unit code (SIL) and extends to testing with isolated but real target control units (HIL). It is desirable to reuse any test drive scenarios across all development phases and different execution environments as unchanged as possible.

By defining input formats to compliant simulators, OpenSCENARIO and OpenDRIVE form the basis for this reusability. According to the OpenSCENARIO XML specification “a scenario is a description of how the view of the world changes with time, […] this encompasses […] both world-fixed (static) elements such as the road layout and road furniture, world-changing (dynamic) elements such as weather and lighting, vehicles, objects, people, and traffic light states.” [ASA24]. While OpenDRIVE covers the static part of the scenario, OpenSCENARIO addresses the dynamic content.

The relevant scenario content can stem from various sources, including recorded test drives, accident databases, expert knowledge from function developers, or regulatory requirements. Euro NCAP, for example, provides descriptions of collision scenarios to test active safety systems of vehicles. Autonomous emergency braking (AEB) and forward collision warning are the most relevant of these systems. Although these tests are not mandatory, one may count them towards the regulatory requirements. The specified scenarios cover the pre-dominant accidents found in relevant databases [GER15] and include collisions between the vehicle under test and a variety of targets including passenger cars [EUR24a], motorcycles, bicycles, and pedestrians [EUR24b]. This and the fact that the ratings by Euro NCAP are of high importance for OEMs make these scenarios well-accepted and widely used, both on real test tracks and in simulation.

2 Motivation

Simulations of Euro NCAP scenarios are conducted by the OEMs and their suppliers. Furthermore, numerous simulators exist, many of them with proprietary scenario descriptions. Therefore, it must be suspected that many implementations of the scenarios in various formats have been created in the past, both by users of simulators and tool providers. This, undoubtedly, has many disadvantages: duplicated efforts, non-reusable scenarios in proprietary formats and potential misinterpretations of the scenario definitions to name just a few. To alleviate these issues, we decided to comprehensively evaluate the suitability of the open standards OpenDRIVE and OpenSCENARIO for modeling various scenarios [FUN24]. Specifically, the following aspects were examined:

- The use of OpenSCENARIO XML parameters to avoid proprietary pre-processing of simulation input data.
- The suitability of the OpenSCENARIO XML Synchronize Action for generating conflict situations under different initial conditions and parameters.
- The functional capabilities related to logical scenarios in OpenSCENARIO XML for parameter variations.
- The possibility to re-use the scenario descriptions and the post-processing of the simulation results from MIL over SIL to HIL.

After an initial implementation had proven OpenSCENARIO XML and OpenDRIVE capable of fulfilling these requirements, Vector decided to contribute its implementation of these scenarios open source on Github [VEC02].

The goal is to avoid duplicate work within the community and to foster discussions about the correct interpretation of the standards and scenario descriptions by Euro NCAP.

3 Implementation using OpenSCENARIO XML, OpenDRIVE and MDF

Euro NCAP provides test protocols free of charge that contain the descriptions of the tests including the scenario definitions. These are made available as textual descriptions and sketches, but also tables with parameters that shall be varied, like the speed of the vehicle under test. Furthermore, assessment protocols are available that describe how to calculate the ratings after the test conduct [EUR24c], [EUR24d]. The vehicle and environment simulator Vector DYNA4 [VEC01] natively supports both OpenSCENARIO XML and OpenDRIVE as simulation input formats. Hence, the implementation and simulation of the scenarios was possible without any intermediate conversion to proprietary input formats. The findings of the implementation can be summarized as follows:

1. NCAP static parts in OpenDRIVE
    - Simple straight roads and symmetrical intersections allow for easy creation of matching OpenDRIVE descriptions.
2. NCAP dynamic parts in OpenSCENARIO XML
    - The OpenSCENARIO Synchronize Action is used for the behavior descriptions in many of the scenarios: It synchronizes the target entity's arrival at a target position with the vehicle under test and was of immense value to model the desired collisions.
    - Together with this action, the extensive usage of parameters was key to fulfill the goal of avoiding proprietary pre-processing.
    - An apt choice of parameter definitions made it possible to translate the parameter tables from Euro NCAP directly into OpenSCENARIO XML variation files.
    - The initial set of developed and published scenarios has been made such that the largest possible set of features is already covered, especially regarding the movement of the vehicle under test relative to the target. Therefore, longitudinal, and perpendicular collisions with a straight moving vehicle under test are included as well as scenarios in which the vehicle under test makes a turn. OpenSCENARIO XML proved capable of all of these, with a minor issue as described in chapter 5.
3. NCAP assessment based on MDF results
    - ASAM MDF is used for the recorded data, when simulating the scenarios in DYNA4.
    - A Python-based reporting then automatically calculates the Euro NCAP ratings based on key performance indicators such as impact speed or collision avoidance.

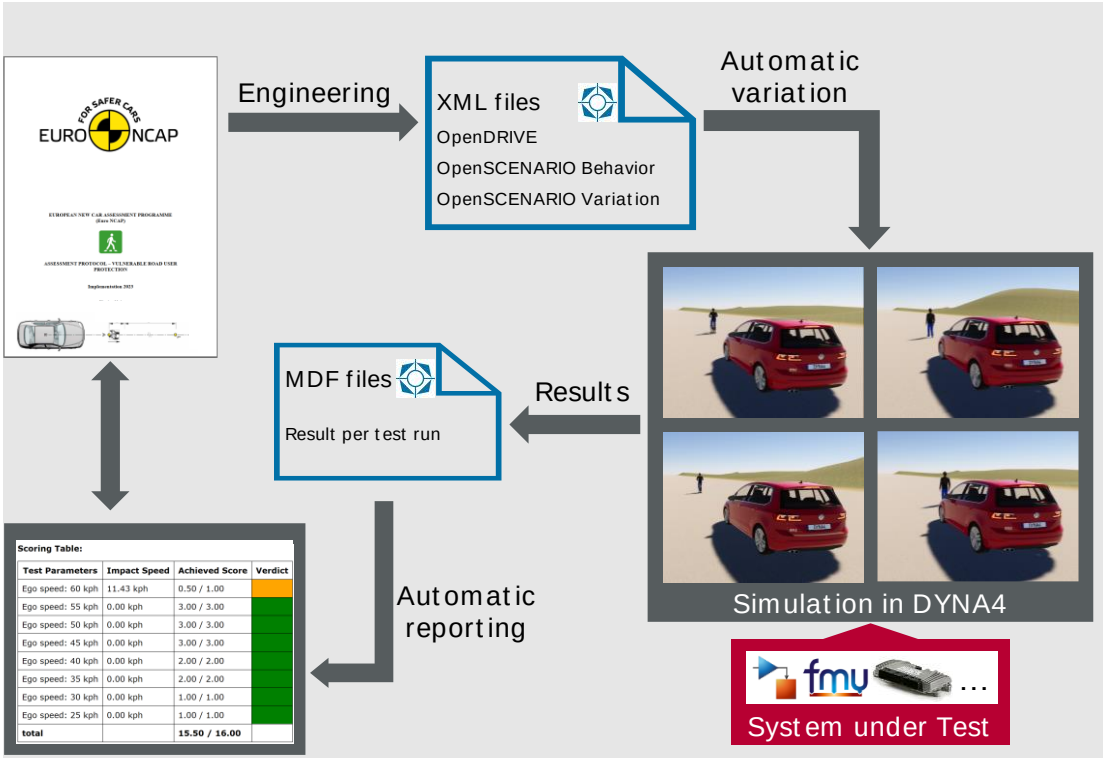

Figure 1: Workflow for creation, simulation, and reporting of Euro NCAP scenarios

The entire workflow from creation of the scenarios based on the Euro NCAP protocols up to the reporting is summarized in Figure 1.

4 Re-usability in different execution environments

As Figure 1 suggests, the system under test may be available in different stages throughout the function development and can range from a Simulink-based model or as an FMU (MIL) through control unit code (SIL) to real target control units (HIL). The interfacing to the system under test and the execution environment of the simulation change according to these stages. The DYNA4 models can be compiled for different environments such as Windows and Linux Executables, FMUs and various real-time hardware targets. Independent of the execution environment, the DYNA4 models directly ingest OpenSCENARIO XML and OpenDRIVE. In this way, a full re-usability of the scenario definitions is ensured. Only the parameter variation should be performed in an upstream step to avoid this calculation overhead when performing tests with real-time hardware and reduce the effort to handling the switching of parameter sets within the test automation. For example, Vector CANoe can be used for the test execution for SIL and HIL tests with DYNA4 models directly embedded. Test designs with Vector vTESTstudio then switch through the different pre-calculated parameter sets.

5 Future Work and Conclusion

As the implementation of the Euro NCAP scenarios in the OpenSCENARIO XML format is time-consuming, not all scenarios described in the test protocols by Euro NCAP have been implemented and published yet. The remaining scenarios will be added to the Github repository [VEC02] successively. As the currently implemented scenarios already cover most features, no further obstacles with regards to the standards are expected. However, during the implementation, a likely candidate for future standardization has been identified already: For scenarios in which the vehicle under test makes a turn at an intersection, Euro NCAP prescribes concatenated trajectories using straight, clothoid and arc elements. Such trajectories are supported by the latest OpenSCENARIO XML version 1.3.

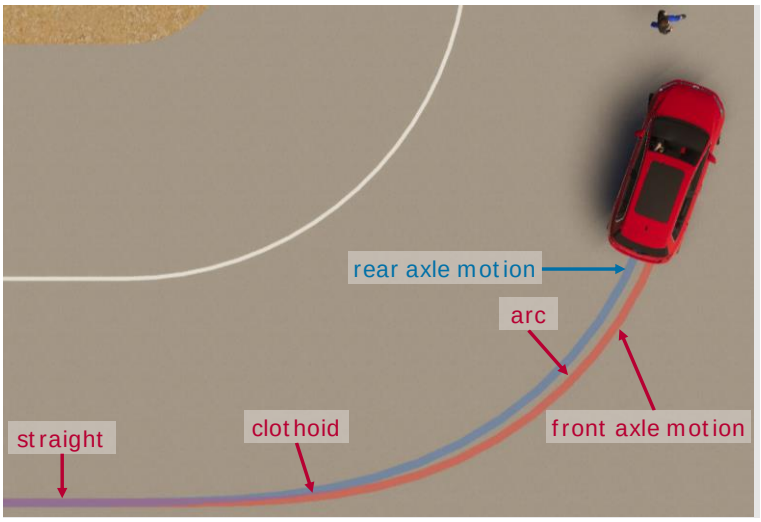

Figure 2: Front and rear axle motion when following a prescribed trajectory of a turning maneuver

OpenSCENARIO XML, however, uses the center of the rear axle as the control point for following trajectories, while Euro NCAP specifies the center of the front axle, which is a common reference coordinate system for vehicle dynamics simulation. Figure 2 highlights the difference of front and rear axle motion when following such trajectories. Until a feature supplement in the standard is possible, a standard-compliant but still proprietary controller property was introduced in DYNA4 to move the control point accordingly.

Another issue that has been identified does not affect the result of the scenario execution but would improve the style of the OpenSCENARIO XML files. As of now it is possible to store certain information in catalog files for improved reusability. This feature of OpenSCENARIO XML has been extensively used for the implementation. However, it is not possible to refer to certain values of the catalog entries. Therefore, certain values like the dimensions of the vehicle under test and the targets are duplicated among the catalogs and the actual scenarios, which deteriorates maintenance.

Altogether, the ASAM standards OpenSCENARIO XML and OpenDRIVE proved to be capable of modelling the scenarios described by Euro NCAP for the assessment of active safety systems. As desired when initiating the implementation of the scenarios, it was also possible to avoid any external pre-processing, even for the parameter variations. As a result of this and the architecture of DYNA4, it could also be proven that the standardized input formats are directly suitable for simulation execution in different environments for use-cases ranging from MIL over SIL to HIL tests. The same holds true for the post-processing of results as the simulations' output is independent of the execution environment.

6 References

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