The Eclipse Working Group openPASS – an open source approach to safety impact assessment via simulation

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ABSTRACT

In modern vehicles, driver assistance and safety systems are increasingly supporting the driver in complex or dangerous situations by applying preventive strategies. These strategies include warnings, enhanced braking assistance, and automatic interventions to increase road safety. A key challenge is to quantitatively assess the safety performance in terms of reduction or mitigation of traffic accidents, as these real-life effects are key considerations for all stakeholders involved in the planning of future mobility. Accident re-simulation and stochastic traffic simulation provide large opportunities to predict these effects. Both approaches require widely recognized models and reliable simulation. Hence, in order to agree on validity and reproducibility, the overall method, from the combined use of heterogeneous data sources in modeling to simulation metrics must be transparent.

Virtual "what-if" re-simulation based on reconstructed accident trajectories may show if a system had affected particular accidents on a case-by-case basis. However, reconstruction relies on limited traces and does not cover the complete traffic situation. Stochastic traffic simulation based on accident data can model how conflicts emerge and how to avoid or mitigate them. However, their exposure in real world traffic systems is not known. "openPASS" (**open p**latform for the **a**ssessment of **s**afety **s**ystems) will provide a free access, functional framework for a reliable, state-of-the-art, and standardized method of completing

effectiveness analysis. This will allow incorporating additional data source and results from other evaluation methods: e. g. track tests or driving simulator experiments. These laboratory conditions deliver precise measurements for specific and thus limited points. In field operational tests, the functionality in real-world normal driving conditions can be observed. Accident data outlines target populations and size of potential impacts. For future validation and verification, ex-post statistical analysis should show significant reductions for specific vehicle models in large data sets, after a system is introduced into the mass market.

The openPASS Working Group was founded in August 2016 to jointly develop a harmonized tool for effectiveness evaluation within the scope of the Eclipse Foundation. This group aims at fostering open source solutions for simulation tools in the field of active and passive vehicle safety. The open source approach makes use of infrastructure and the vivid ecosystem of the Eclipse foundation that provides synergies of both professional software development and open source spirit. Resulting code of the first related Eclipse project sim@openPASS is expected to be published in Q2/2017.

Related methodologies are discussed in P.E.A.R.S. (an initiative in this field) and PEGASUS (a German research project) and aim to combine different assessment approaches, in order to achieve overall valid results. OpenPASS addresses this need for a common framework: applicable metrics, thorough data basis, comprehensible models of driver behavior and sensor effects – and flexible, modular simulation platforms. This paper shows various options how to get involved: use of the software, providing scientific input, creating new open source modules, joining the Working Group.

OpenPASS offers an open source platform designed around open standards which fulfills requirements such as modularity, transparency and performance. It will foster a creative eco-system of exchange for traffic and vehicle safety research, module development and data acquisition to support analyses that make present traffic systems a safer system with less or – optimally - no casualties.

OBJECTIVE

Driver assistance and safety systems are increasingly supporting the driver in complex or dangerous situations. They are designed to help the driver or take over the control of the vehicle to eventually prevent accidents. The strategies of these systems include warnings, enhanced braking assistance, and automatic interventions. A key challenge is to quantitatively assess the safety performance in terms of reduction or mitigation of traffic accidents. Predicting or determining real-life effectiveness of these systems delivers valuable input to considerations of many stakeholders involved in shaping future mobility.

Customers, i.e. individual drivers, want to understand the potential benefits of the systems available in their vehicles. To a majority of customers, driver assistance and safety systems are still novel technologies, since the average age of vehicles e. g. in the European fleet is above 9 years and still increasing [1].

Automotive manufacturers and suppliers need clear guidance from accident research regarding the question; which are the relevant scenarios for future systems in order allocate significant investments in effective and feasible concepts. Especially new challenges concerning fuel consumption, emissions, automated driving, and electric mobility can be tackled more effectively, if future system requirements adapt to changing scenarios and allow for new concepts.

Insurance companies ascertain that standard equipped driver assistance and safety systems have “ex-post effects” in volume models [2, 3]. They stilll need valid projections of changes in accidents data (claim frequency, claim value) due to technological changes in order to adjust their products and incorporate new incentives.

Public domain institutions like regulation agencies or consumer protection bodies, e. g. “NCAPs” (new car assessment programs), aim to reflect overall optimum values in road safety in their star ratings. On the one hand, their core issue is the validation testing of basic requirements (e. g. passive safety performance) in order highlight outliers. On the other hand, the NCAP bodies want to use their rating schemes as incentives for manufacturers to equip as many vehicles and models as possible with advanced technologies [4]. Hence, NCAPs need an always up-to-date, detailed and integrated understanding and prediction of effectiveness of technologies – and their impact on future accident trends. In order to regard improvements in crashworthiness and avoidance capabilities, effectiveness assessment should be a basic input for these institutes to develop ideal rating strategies.

This paper intends to explain how “openPASS” (open platform for the assessment of safety systems) will fill the needs of the different stakeholders involved in effectiveness assessment.

METHODS & DATA SOURCES

Given these multilateral objectives, the need for a harmonized and transparent way of assessing ADAS safety performance is high. Conventional testing methods of assistance and safety functions, as currently used, include hardware-in-the-loop procedures (e.g., for sensor / algorithm testing), testing of technical factors, and testing of human factors (e.g. in driving simulators or on test tracks). To a limited extent, real traffic testing (e.g. in controlled observational studies or in field operational tests) can be used to obeserve the behavior as intended in the field. However, accidents are sparse events, so validation and verification of a function reducing specific accidents can hardly be addressed with driving tests in a manageable time.

Each of these methods provides an important insight into the safety effectiveness of a system on a particular aspect with models influencing the likelihood and severity of an accident. But for complex active safety problems, conventional testing methods are rarely sufficient to cover all relevant processes and make sound estimates of the overall safety effects in a traffic environment. An important challenge is to assess field effectiveness with adequate validity: Any key aspect that is assessed with low validity will disproportionately compromise the validity of the entire assessment process, given sufficient sensitivity of that particular aspect.

Accident re-simulation or stochastic simulation

Accident re-simulation and stochastic traffic simulation provide large opportunities to predict these effects:

Accident re-simulation: for example the GIDAS project [5] collects representative samples of in-depth accidents in two investigation areas (Hanover and Dresden), which are reconstructed based on traces, vehicle damage, and witness statements. These pre-crash trajectories are extended up to 5 seconds prior to the first impact. The current "pre–crash matrix" (PCM) database contains these trajectories for more than 8,000 cases. The PCM database enables accident researchers to investigate why the accident happened and whether driver assistance or safety systems could have prevented the accident. However, these datasets are limited in their insight on complex conflict mechanisms and interaction since reconstruction relies on sparse information and simple models. Furthermore, only vehicles involved in the collision are reflected in the data, while surrounding traffic is not reflected in the data.

Stochastic traffic simulation: the proceedings in the field of traffic psychology lead to advanced driver models, which do not simply model the driver as a controller, but reflect human skills and properties by incorporating their statistical uncertainties. Hence, in addition to providing input to traffic infrastructure planning, more and more insights on accident occurrence can be derived from "virtual conflicts" generated with realistic driver models. Compared to reconstructed scenarios as input data, these virtual accidents are more of a forward simulation. However, as this method reflects stochastic information. Generated critical or accident scenarios need to be validated as their exposure is unknown.

Additionally, there are recent concepts from the field of virtual testing making use of machine learning that cover both the use of real-world data and the use of abstract, but clearly defined scenarios with parameters reflected by statistical distributions. Algorithms are trained to objectively determine critical events in traffic data, evaluate these events, and "learn" new scenarios and parameter distributions (see "Discussion" on the German research project PEGASUS [6]). For the validation and approval of automated driving functions, detailed and reliable simulation approaches are required to replace field test to a large extent.

The before mentioned approaches require widely recognized models and a reliable simulation approach. The overall method must be transparent in order to be comprehensible. It must be capable of generating robust, valid, and reproducible results. . This postulated transparency must be ensured when using existing models or creating new models to take new characteristics based on the combined use of heterogeneous data sources into account. This transparency must also account for simulation metrics, so it is clear how the results are evaluated and discussed.

Methodology for safety impact assessment implemented by openPASS

The approach implemented by openPASS is based on multi-agent based, stochastic traffic simulation as described by the P.E.A.R.S. initiative [7] – see Annex for an illustration of detailed workflow. The goal is not limited to harmonizing models and delivering software of high quality. OpenPASS also intends to "unify" both approaches previously described by enabling the user to leverage the valuable information of real world accident data as validation benchmark for virtual accidents.

Models of traffic scenarios (including road layouts, cognitive, and behavioral models of traffic participants) and environmental conditions are combined with models of vehicles and their embedded safety systems in one simulation platform. Due to the modularity of software components, the same platform and relevant models can be used for accident re-simulation as well. One possible work flow of openPASS is described hereinafter:

First, target scenarios of the system of interest need to be identified. The scope of the virtual experiment is formulated as a detailed description of the target scenarios on the basis of traffic and accident data.

Second, the target scenario statistical exposure models are determined in order to generate representative samples for the simulation. Statistical exposure models (e. g. traffic conditions, infrastructure characteristics, environmental conditions) provide distribution functions of context variables that could influence the system effectiveness in a certain scenario. For the use case of re-simulating trajectories leading to real accidents, modeling and adjusting models are not necessary, since ideally the sample of trajectories would be representative of the accident population of interest.

Statistical uncertainties due to variations (e. g. driver reaction or sensor performance) need to be considered as stochastic parameters of the models.

Requirements for openPASS

Market research was conducted in an early phase of the project, but it has shown that none of the currently available simulation tools can meet all key requirements. Derived from the approach sketched above, the most important factors are performance, flexibility and transparency. The combination of the three aspects is especially crucial for making this approach a success.

<u>Performance</u>: The performance must be sufficient to provide the required statistical precision within a reasonable time-frame (.e.g. calculating large numbers of scenarios). A high number of runs must be conducted much faster than real time.

<u>Flexibility</u>: scenarios should be easily adaptable, which means not only varying parameters or other slight modifications. The simulation environment must be easily adapted to completely different use cases (e. g. highway traffic or complex crossing conflicts with bicyclists).

<u>Transparency</u>: the software design and architecture should encourage usage in third-party funded research projects. To this end, the adaptation of new interfaces or the implementation of scientific insights in new or existing modules should be possible.

Furthermore, the platform should allow for easy-to-use applications (low barriers for entry for all users) as well as for advanced use cases.

Results

A detailed assessment of various entities revealed that a working group under the roof of the well-known and established Eclipse Foundation meets all requirements. Hence, the founding members of the working group and the Eclipse Foundation established a working group aimed at strategically and tactically developing a performant, flexible and transparent tool for the harmonized prospective assessment of safety systems [8]. The working group was founded in August 2016 and aims at fostering open source solutions for simulation tools in the field of active and passive vehicle safety. The open source approach makes use of infrastructure and the vivid ecosystem of the Eclipse foundation that provides synergies of both professional software development and open source spirit.

Figure 1. Logo of openPASS

The working group is structured as follows:
Four different classes of membership exist. First, driving members define project objectives, project strategies, and finance the project. They are the main actors within the working group. Second, service providers, comprise developing, deploying, and maintaining the openPASS relevant components. They are mainly involved in the realization of the project. Third, user members use the software and results while also participating in working group activities. Fourth, guests may be invited by the other member classes to get to know the project ideas as they are potential new partners or entities to seek information or advice.

Besides a diverse member class structure, there are different working group bodies to steer, realize, control, and inform the group. The steering committee is the body defining the strategy of the project and ensure project deliverables are met in a timely manner. The architecture committee has the responsibility to ensure the functional, non-functional, and technical consistency of the project according to the project strategy and goals. The quality committee defines the applied quality kit and maturity process while also ensuring the quality of results. Lastly, general assembly enables all participants to get up to speed with committee work and progress regarding the project.

The working group bodies are responsible to ensure integrity of the entire project. According to Eclipse's regulations, different "projects" may be part of the working group to develop source code in accordance with the working group objectives and requirements. The initial project that was founded is called "sim@openPASS" [9], which aims to release the software openPASS. The first milestone of sim@openPASS is to release an initial commit bringing together the committed initial contributions of the driving members. This version of openPASS is configurable via a Graphical User Interface (GUI) with limited access. In the GUI, the user may firstly, load a scenario, secondly, configure a system by dragging-and-dropping system components, parameterizing, and connecting them, and thirdly, run simulations with a novel simulation core which also accounts for collisions. This rudimentary implementation is the backbone for further enhancements and updates.

By end of Q2/2017, the second milestone is to release a version that is capable of estimating the effectiveness of driver assistance and safety systems in simple scenarios. It is aimed for a functionality that is more or less equal to commercial and proprietary state-of-the-art tools available today.

CONCLUSIONS

Currently, in openPASS and the adjunct project sim@openPASS, new components and features are under development and will be committed subsequently to the Eclipse repositories. For example, the collision detection functionality is being improved to deliver more detailed interpretation of the virtual accident not avoided by the modeled functions. The GUI is being extended to incorporate general functionality in harmonized GUI modules, while still allowing easy modifications via a plug-in architecture. Based on the assessment of simulation tools available today, the founding members partnered with the Eclipse Foundation in order to develop a new high performance, flexible, and transparent simulation software aimed to assess the effectiveness of vehicle ADAS systems in the highly complex environment of traffic safety. The working group is always open to new members or new ideas for new projects. Potential involvement in openPASS is available through many level: using the software, testing the code and reporting bugs or new ideas, writing additional code and commit it open source – or support the working group and fund current development.

As mentioned previously, the R&D project PEGASUS funded by the German government is currently a driver of similar harmonization activities in the field of virtual safety systems assessment. The overall research questions of PEGASUS are what criteria have to be fulfilled for highly automated driving and what tools and methods are needed to assure the fulfillment of these requirements [6]. Its methodology aims to seamlessly integrate field tests, proving ground tests, and virtual tests – which means vice versa that virtual testing must use fidelity models of reliably high validity (sensors, scenarios, conditions).

The open standard "OpenSCENARIO" is developed and used in PEGASUS, which allows flexibly defining and describing dynamic behavior of agents in a virtual OpenDRIVE road environment [10]. OpenPASS is aiming to synchronize its logging processes to this XML-based format. It is also planned to be the "standard interface" for initial conditions of agents in simulations runs. In PEGASUS, all scenarios and parameter distributions are implemented in OpenSCENARIO, making the project a test use of this recently published standard.

The “Open Simulation Interface” is a further activity which is driven by PEGASUS, but will feed into openPASS. The objective is to harmonize sensor models by defining the input interface - how the ground truth from simulation framework is provided to the sensor - and the output interface - how sensors are providing output to the function (input to environment model). This allows combing different sensors and using virtual ground truth data with statistical models describing sensor phenomena [11]. OpenPASS is adapting its interface to make use of the upcoming sensor models complying with this standard.

The methodology of virtual assessment of safety impacts has been under discussion in the P.E.A.R.S initiative since 2012 [7]. Ideally, openPASS offers the members of the group the open framework for a reference implementation. But the “openPASS ecosystem” should further encourage users and researchers in the adjacent fields to implement their scientific findings and commit them as “openPASS modules”. The interaction of openPASS and P.E.A.R.S enables a more detailed and deepened discussion of models, validation and verification of reference scenarios. Finally, it will allow virtual assessment to become a major pillar of approval and testing procedures in future automotive R&D.

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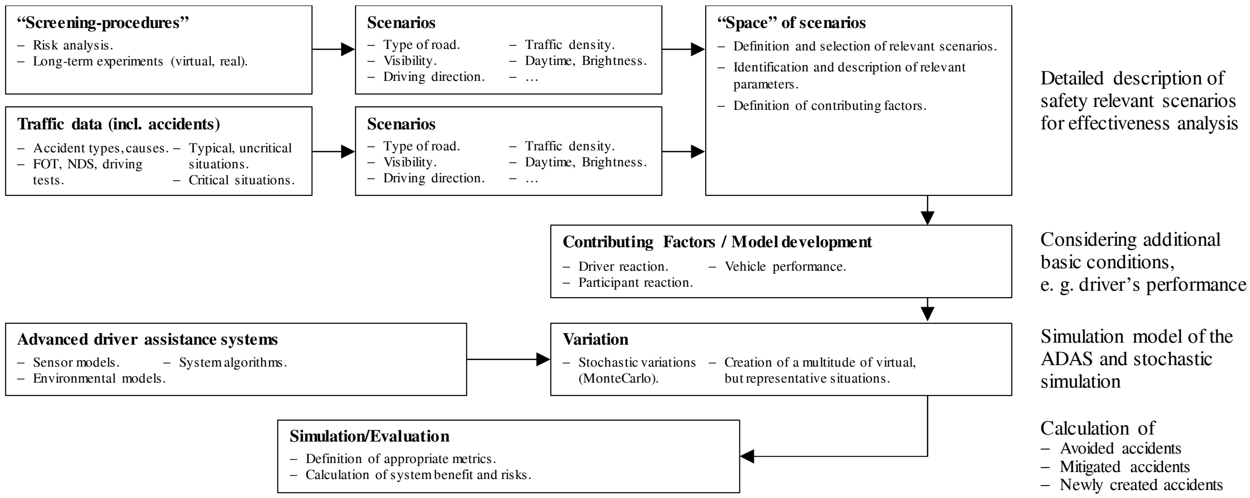

Annex - Figure 1. Methodology of virtual experiments with openPASS