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# Simulation of Road Traffic Accidents Related to ADAS Systems in PreScan

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***Abstract***

*This paper describes a simulation of a specific accident reconstructed in PreScan software. Through this, we show that the PreScan software can be efficiently applied in accident reconstruction, particularly the operation of ADAS systems can be explored and analyzed. Beyond this, we also demonstrated during our research that the investigated simulation environment can be used efficiently to evaluate the reliability and safety of electronic control units developed to control highly automated vehicle functions. Consequently, we also proved the applicability of concept related to the hybrid multi-agent simulation environment (especially considering the ZalaZONE ecosystem) including differently controlled components (e.g. fully autonomous, human-driven or highly automated vehicles). In the simulation, we examine the Adaptive Cruise Control (ACC), Lane Keeping Assist (LKA), and Automatic Emergency Braking System (AEBS) in the accident. Evaluating the results, we found that the lane-keeping system is very sensitive to the quality of pavement signals. In the selected case, poor-quality signs likely played a major role. On the other hand, it was clear that the properly working safety systems would have been effective in reducing collisions speed, and a longer tracking distance would have had a positive effect. In the case of the adequate operating FCW, the driver would have had sufficient time to intervene and stop the vehicle. In the final section, we analyzed how PreScan can be used to connect an external device to the simulation environment.*

***Keywords:*** *Adaptive Cruise Control (ACC), Automatic Emergency Braking System (AEBS), Lane Keeping Assist (LKA), PreScan*

## 1 Introduction

Regarding a crash sequence shown in Fig. 1, Advanced Driver Assistance System (ADAS) has two significant roles in a vehicle. Under normal driving conditions, it acts as a convenience feature by enabling automated driving and reducing the workload of the human driver. When the danger of a potential crash appears, the safety side of ADAS becomes dominant. By warning and assisting the driver and/or taking preventative actions automatically, they are effective at avoiding or at least mitigating the effects of a collision. Most modern vehicles already have some driver assistance systems installed. Beginning from 2022 it has become mandatory to include LKA and AEBS in all new models of passenger cars sold in the EU. However, these systems are prone to malfunction and still require supervision from the human driver. To further improve these systems, it is important to analyze crashes where ADAS failed to intervein.

## 2 Related works

PreScan is also a widely used co-simulation framework used primarily to develop automotive functions, as its sensor simulation capabilities make it well-suited for Hardware-in-the-Loop (HiL) development and validation tasks.

Miao, Q et al. [2] used PreScan to develop control algorithms for different ADAS and evaluate and optimize the performance of such systems using multiple traffic scenarios [6] based on real-life data. They found PreScan to be an effective, low-cost, and simple environment for developing safety systems [8], [9], [10].

Son, T. D. et al. [3] proposed a co-simulation framework for developing and testing ADAS and Autonomous Vehicle (AV) systems. They used Siemens Simcenter Amesim to develop the control algorithm, which provides a detailed vehicle dynamic model for the simulations [7], [11]. The Simulink-based Amesim simulation is interfaced with PreScan, which is responsible for simulating the traffic scenario and generating sensor data using detailed sensor models to test and validate the control algorithms. The co-simulation enables the testing and validation of the systems to be more effective, saving time and cost by reducing the number of real prototype tests.

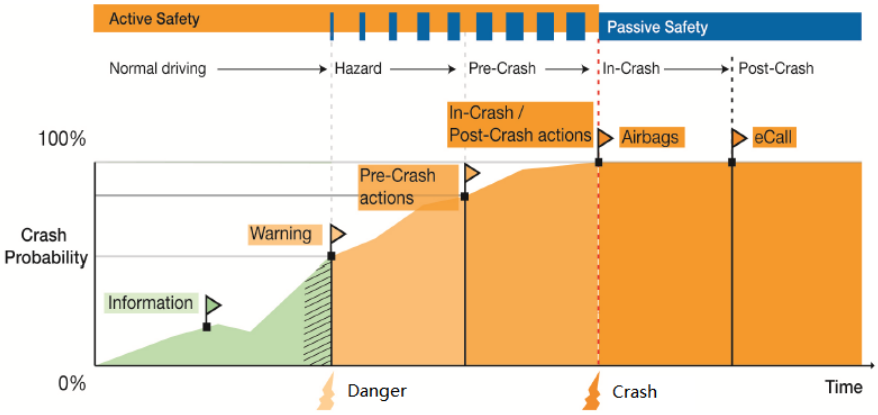


***Fig. 1*** *Crash sequence [1]*

Another group of researchers created a test system for the real-time evaluation of Lane Departure Warning System (LDWS). This contained a virtual reality system running PreScan to simulate different scenarios, a real-time platform to run a real-time vehicle model, and a real-time controller for the LDWS hardware. The LDWS was aimed at a monitor showing PreScan's generated environment and communicated with the real-time controller via CAN-bus. They tested the system with multiple LDWS hardware from different manufacturers and found that PreScan's versatility in the road, traffic, and environmental conditions makes it ideal for this kind of testing [4].

Similar studies describe the need for creating a complete test program for intelligent vehicle systems to standardize and speed up the validation and approval of such systems. To achieve this, they propose a multi-stage method consisting of simulation, hardware-in-the-loop testing, and test track testing. They summarize the scenario-building process of PreScan and describe the benefits of using it for the simulation stage. It enables testing the systems in a wide range of scenarios in a relatively short time which can also be automated. When a system passes these tests, the most important and critical scenarios are further tested in the consequent stages [5].

The implemented solution demonstrated that the applied simulation framework could be used efficiently to evaluate the reliability and safety of electronic control units developed to control highly automated vehicle applications. In accordance with this, we also proved the correctness of our concept, stating that it is possible to develop a hybrid multi-agent simulation environment including differently controlled components (e.g., fully autonomous, human-driven, or highly automated vehicles). The framework based on the new system concept can be deployed efficiently in cooperation with a proving ground (e.g., ZalaZONE [12]) environment applying digital twin technology, providing a feasible and reliable balance between the costs of test and validation processes and the high number of test scenarios required.

## 3 Methodology

PreScan was used to recreate a crash scenario based on real accident data where the failure of ADAS was found as a contributing factor. The chosen crash involving a Tesla Model X operating in Autopilot mode happened on March 23, 2018, near Mountain View, CA. According to the crash report issued by the NTSB (National Transportation Safety Board), Tesla was cruising on a multi-lane highway in the HOV (High-occupancy vehicle) lane. Approaching a highway interchange, a left exit HOV lane opens, which gets separated from the other lanes by a concrete barrier. Leading up to the barrier, the Tesla entered the gore area between the two HOV lanes and crashed into a nonoperational crash attenuator placed at the beginning of the concrete barrier. Data gathered from the Event Data Recorder (EDR) showed that Tesla's assistance systems were activated leading up to the crash but didn't recognize the danger, nor did the driver make any preventive action.

Tesla's Autopilot systems consist of multiple ADAS components. In the PreScan simulation, LKA, ACC and AEB systems' functioning were analyzed. The applied LKA model uses a camera sensor to identify and follow lane markings. The ACC and AEB both use a long-range (150 m beam range, 9° horizontal beam angle) and a short-range radar (60 m beam range, 80° horizontal beam angle), modeled with PreScan's Technology Independent Sensors (TIS).

During the investigation, the NTSB found that the lane line on the left side of the gore area was more prominent and visible than on the right. It was proposed that this difference between the lane lines might cause the LKA system to follow the left line, explaining why the vehicle entered the gore area. PreScan's line parameters "Fade" and "Hole" was used to determine how bad line quality affects the performance of the LKA system.

In an accident investigation, it is also essential to evaluate whether or how the accident could have been prevented. There was no identified reason why the ACC and AEB systems failed to recognize the obstacle. To assess these systems' impact on collision speed – should they function correctly – headway times of 0.9 seconds (minimum setting on Tesla) and 2.0 seconds (maximum setting) were assumed. It was also evaluated whether the driver would be able to stop the vehicle before the collision, the AEBS should issue an FCW (Forward Collision Warning) alert. For this simulation, a reaction time of 0.7 seconds was assumed for the driver after the FCW alert.

The last section explores the concept of using PreScan as an environment for testing and evaluating ADAS or Automated Driving Systems (ADS) running on external hardware. We created an interface for connecting to the PreScan simulation and running the algorithms in real-time for Processor-in-the-Loop (PiL) or HiL tests. Thanks to the Simulink-based PreScan simulation, various networking blocks are available to establish communication with an external device connected to the same local network. We used a Raspberry Pi 4 Model B to test the connection, running a UDP server for communication and a simple control algorithm. Once the PreScan simulation is started the Simulink model is configured to connect to the server on the Raspberry as a client and send the required signals for the control algorithm. The Raspberry then feeds back the control signal to Simulink, which is propagated to the vehicle dynamic model. The proposed architecture is shown in Fig. 2.

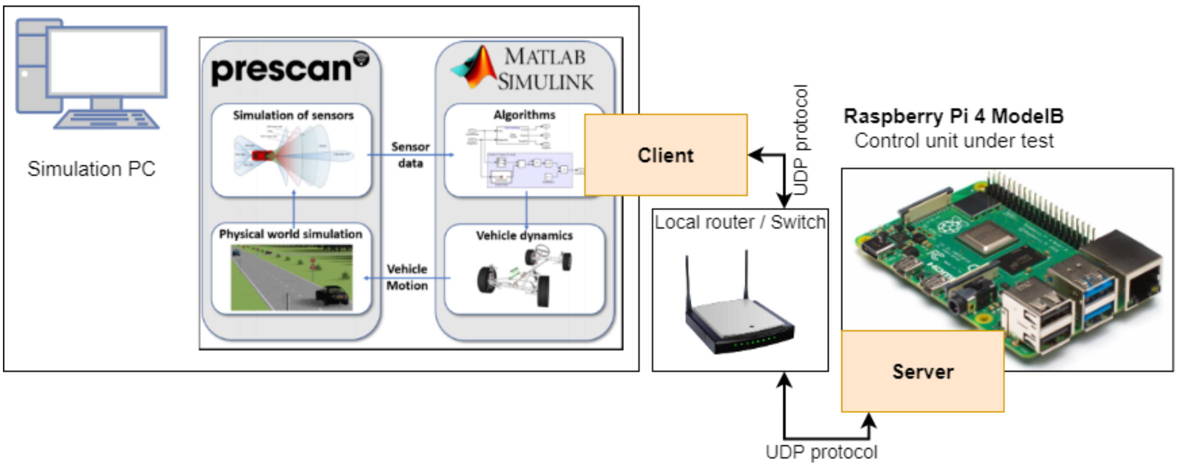


***Fig. 2*** *Proposed system architecture for communicating with external hardware*

The control algorithm receives throttle and brake signals along with simulation time. It is configured to echo back the received signals until a particular simulation time, after which full braking is initiated regardless of the incoming signals. The test can be interpreted as a hardware failure or even a cyberattack scenario where a malicious third-party intercepts the original signal and injects its own. By comparing the sent and received signal in Simulink, the latency introduced by the communication was measured to test whether this method is able to provide real-time performance.

## 4 Results and evaluation

By setting the right channeling line's both "Hole" and "Fade" parameters from the ideal 0% to 20% the LKA system's performance starting to degrade. At the start of the gore, where the two lines separate LKA starts to follow the left line by making a left steering input. However shortly after it is still able to correct itself by picking up the line on the right side of the gore and returning to the lane's centerline. This steering maneuver is shown on Fig. 3. By raising both parameters to 40% the system completely ignores the right line and continues to direct the vehicle into the gore area. This is likely caused by the edge detection algorithm failing to identify the lower contrast and fragmented right line as the lane boundary.

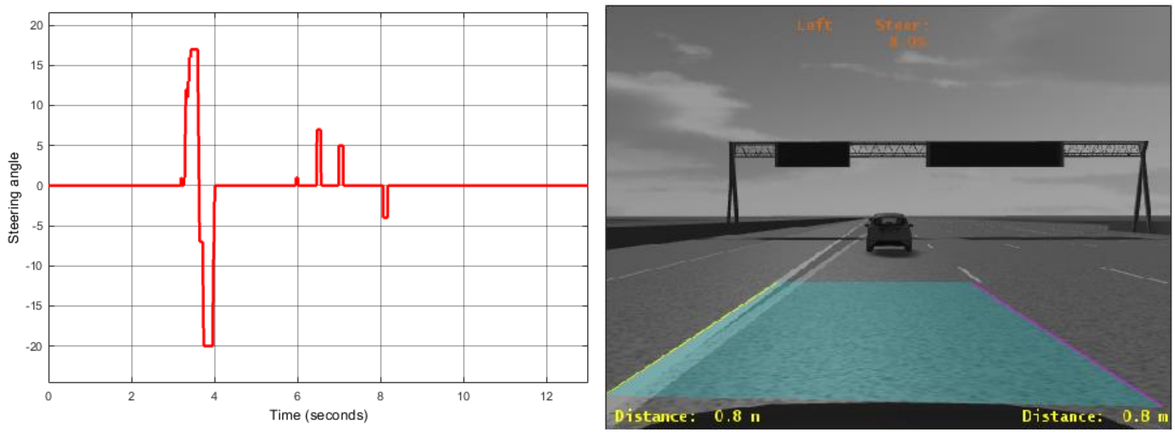


***Fig. 3*** *LKA system's steering input and identified lane boundaries*

In the accident the driver set the ACC systems demanded headway time (HWT) to the minimum 0.9 seconds. The simulations show that a properly functioning ACC system with this setting is still able to identify the crash attenuator as obstacle 2.5 seconds before impact but only starts braking 1.2 seconds before impact. Even with the short time available and limited braking capabilities of the ACC, it still manages to reduce the collision speed from 114 km/h to 99 km/h. With the maximum headway time setting of 2.0 seconds the braking starts immediately after detection which is 2.2 seconds before impact. This further reduces collision speed to 84 km/h.

Enabling the AEBS in the simulations resulted in improved braking. The detection times are identical, but unlike ACC, the AEBS can utilize the full braking potential of the vehicle. With HWT = 0.9 seconds the collision speed is 69 km/h and with HWT = 2.0 seconds the collision speed is 65 km/h.

Assuming the AEBS issues an FCW alert to the driver at the time of detection and the driver reacts to this with a reaction time of 0.7 seconds the simulation shows that he would be able to stop the car before impact even with the minimum headway time setting.

Regarding the Raspberry test system mentioned earlier a latency of 20 milliseconds was measured. This corresponds to exactly 2 time-steps since the simulation was running at 100 Hz. We found this to be acceptable. The benefit of this system is that it is based on UDP protocol which means it is easily scalable, multiple external devices can be connected. Since we are not using a real-time rig, the components can be easily swapped to support rapid prototyping for algorithm development.

## 5 Conclusion

PreScan simulation software – while built for development purposes – can be efficiently applied to analyze the performance of ADAS during an accident and determine what factors most likely contributed to the system's failure. The simulation can be further improved by using system models identical to those that ran on the crashed vehicle, but this is only possible with cooperation from the vehicle's manufacturers because these are protected under intellectual property laws.

We developed a method for testing an external ECU hardware model – that is, running a control program in real-time – to control a vehicle in a PreScan simulation. This work was the first step toward the long-term goal of developing an overall testing environment focusing on automotive electronic control units focusing on the security of the system and its modules, including algorithms, software frameworks, hardware and interfaces.

## Acknowledgement

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