On the Validation of Human Body Models with a Driver-in-the-Loop Simulator

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For the development of passive safety systems, standard simulation models of anthropometric test devices can be used to predict and investigate possible injury risks at specific crash situations. However, these so-called safety dummies are inappropriate for Pre-Crash investigations/simulations due to missing activation possibilities, tuned characteristics for one specific accident scenario and high passive stiffness properties [1]. To validate integrated safety concepts, getting active prior to the crash, an enormous number of different scenarios have to be investigated. Neither real-world driving nor crash-tests will be able to cover these demands. With virtual testing lots of scenarios, crash situations included, can be tested without any risk for human lives. For this purpose, new tools like suitable virtual models of human occupants are required. Human Body Models (HBM) provide a higher biofidelity by direct modeling the human body structure with bones, flesh and skin. Equipped with active muscle elements, the kinematics of these active HBMs can be controlled by arbitrary and reflexive controller patterns [2, 3]. Therefore, they can emulate the behaviour of real human occupants more accurately than dummy models, especially in low-acceleration driving situations. The kinematic, as well as stiffness properties, can be controlled during runtime. To improve the muscle activation strategy and the stiffness properties of current active HBMs, validation processes on the basis of low-acceleration experiments, e.g. [3], are inevitable.

To gain additional validation data for active HBMs, concerning muscle activation and time-variant stiffness properties, we've built up a low-cost Driver-in-the-Loop (DiL) simulator with kinematic feedback in the form of a 6-DOF motion platform, a force-feedback wheel and a bass-shaker at the back of the driving seat. The workflow is based on a simulink-model, provided by PRESCAN, with vehicle models, visualization of the designed scenario and logical operations to ensure reproducible crash scenarios. We extended the simulink-model with interfaces to external applications, see Fig. 1 to improve the driver immersion. In total, the DiL simulator provides visual, acoustic, haptic and kinematic feedback for the driver. The platform is activated by motion cues,

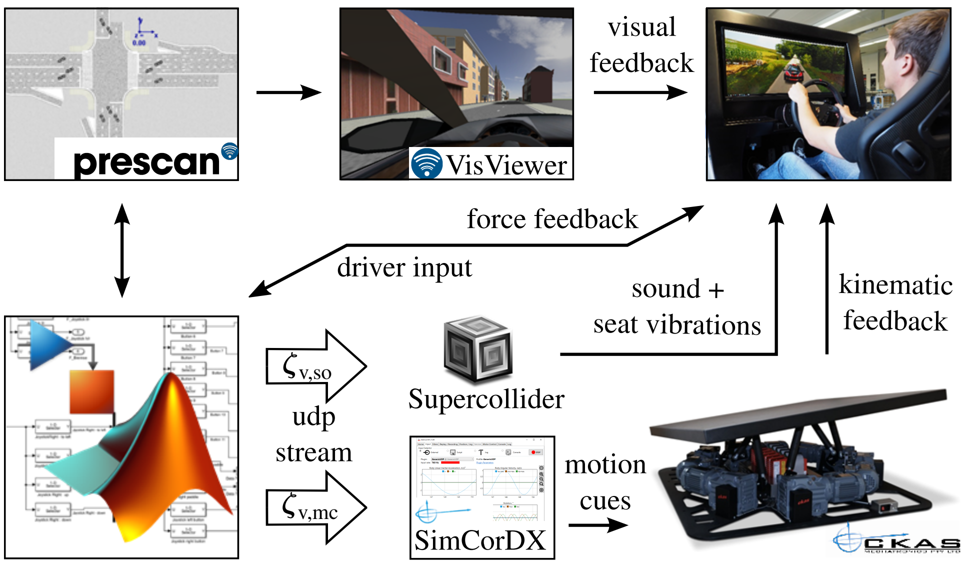

Fig. 1: Workflow of the Driver-in-th-Loop simulator.

computed by the software package SimCorDX. The standard motion cueing algorithms filter the incoming vehicle states $\zeta_{\mathrm{v,mc}}$, consisting of values of acceleration, orientation and angular velocity, and calculate adequate translational and rotational platform kinematics aiming for a good emulation of sensed acceleration for the driver. Due to the small translational movement corridor, special approaches like washout-filter and tilt-coordination [4] are required, to ensure enhanced driving sensation without violating kinematic limits. Tilt-coordination approaches use the assumption that the human vestibular system cannot distinguish translational accelerations from rotational displacements in a gravitational field. The quality of the calculated motion cues can be rated with mathematical models of the vestibular system, comparing the sensed accelerations of the driver in the simulator and those in a real car. Velocity-dependent steering torques, as well as functionalities of driver assistance systems, can be emulated by the force-feedback steering wheel. Car vibrations in real driving conditions, like those induced by engine and road roughness, can be imitated by activating the bass-shaker at the back of the seat. Appropriate states of the vehicle model $\zeta_{\mathrm{v,so}}$, like velocity or engine speed, are transferred to SUPERCOLLIDER via open sound control and are used for the sound synthesis.

To analyze the driver behaviour in the simulator during Pre-Crash situations, kinematics, as well as muscle activation, are monitored. The kinematics are tracked by a motion capture system from OPTITRACK using computer stereo vision with reflexive infrared markers. The cameras with internal image evaluation enable low latencies and high framerates with minimum data transfer. The driver kinematics can be reconstructed on the basis of the 3D-positions of the markers. For transformation of absolute kinematics into relative ones, the simulator itself is also tracked by the camera system. The obtained time-curves of the joint-angles document the executed movement of the driver. Additional to the kinematics of the driver, muscle activation is tracked by electromyography (EMG). This muscle information is inevitable for determination of co-contraction levels at the different joints. Based on the co-contraction level, the stiffness properties of the HBMs can be adjusted to replicate different states of pretension of the occupants, which show a high influence on the injury outcome [5].

The presented setup of a Driver-in-the-Loop simulator allows investigations of driver behaviour in Pre-Crash scenarios, with and without interaction of driver assistance systems. The provided validation data, obtained by the monitoring devices, will be used to improve the biofidelity of active HBMs and their muscle activation concepts. Advanced muscle materials with more physiological properties and activation possibilities, e.g. [6, 7], will enable a more humanlike behaviour of the occupant models after accurate validation processes. These advanced active HBMs, validated for Pre-Crash simulations, can serve as a tool for enhancing integrated safety systems and clear the way for automated traffic with improved real-world safety.

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