

WTI Human Factors Research Facilities

Driving Simulator Optimization: Optimizing Steering Motion Cues in Advanced Driving Simulator

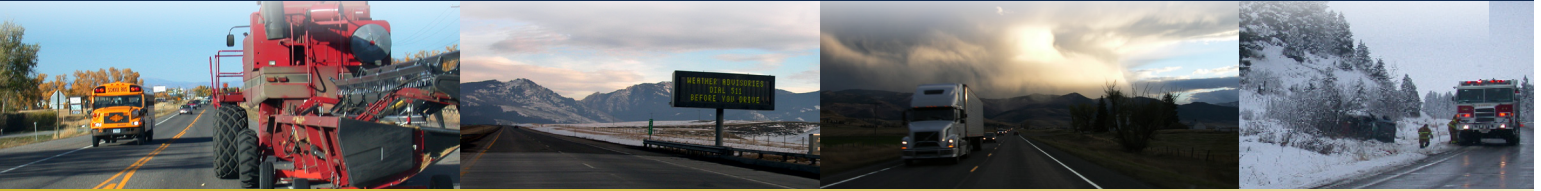
WTI has embarked on a systematic program to optimize and tune its advanced driving simulator so that it provides a realistic research and testing environment capable of yielding results that are transferable to the real world. This tuning and optimization work was completed by Dr. Erwin R. Boer (Entropy Control Inc.) who is an international expert in modeling and optimizing perceptual cues in driving simulators. This involved comparing the response of the simulator including its motion base to driver input (steering, throttle, and braking) with the response of an instrumented vehicle that matched the type of vehicle used to develop the simulator dynamic model (Chevrolet Impala). This press release summarizes the steering feedback component of this systematic process completed with the [WTI Advanced Driving Simulator \(WADS\)](#).

Driving is facilitated by the integrated set of visual, vestibular, tactile, haptic, and auditory cues that together provide information about the state of the vehicle and feedback about the changes in vehicle state caused by steering and pedal inputs. To assure that drivers can drive the simulator with normal levels of mental and physical effort, it is important to assure that as many cues as possible are rendered coherently. In general it is better not to render a cue than to render it in a fashion that is inconsistent with the rest of the cues. This mismatch between the timing, direction, and strength of cues not only degrades performance and increases workload but is also one of the primary causes for simulator sickness. To match the WTI simulator experience to reality, motion cues in the WADS were optimized in the context of rapid lane changing. These lateral motion cues provide the rapid feedback to steering input and if that is sufficiently salient they stabilize heading control.

Accurate and stable lateral control in driving simulators strongly depends not only on the dynamics of the steering system but also on the self alignment torques that are fed back to the steering wheel. From the driver's perspective two components are important:

1. Stable steering dynamics with a moderate stiffness (torque feedback as a function of steering angle) and
2. A quickly responding motion base to obtain rapid feedback about the vehicle response to steering actions.

The former is important to assure that the driver can establish a simply internal model of the vehicle response to steering angle and torque input and the latter is important to assure that the driver can accurately maneuver the vehicle even at high speeds or during complex maneuvers. To optimize and demonstrate the resulting similarity between instrumented vehicle and simulator, a sinusoidal steering profile was generated by the driver at a range of speeds in the instrumented vehicle and in the optimized driving simulator. The resulting cab motions as captured by a 3-DOF linear accelerometer mounted on the roof above the driver's head is show in Figure 1. The response of the cab to the steering angle changes shows that both the real vehicle and the simulator cab show the same acceleration profile that is 180 degrees out of phase with the steering wheel changes. Furthermore, the magnitude of the lateral acceleration (red) on the simulator cab and real vehicle closely matches each other (after correcting for the scale factor (0.06) that is unavoidable in all but the most advanced simulator). It appears that the motions of the simulator cab are noisier than those of the real cab initially, but becomes smooth like the real world case later in the drive (after about 100s) where both the real vehicle and simulator were driving at similar speeds. The fact that the timing and magnitude of the motion base matches that of reality makes for a responsive feeling vehicle that can be driven with confidence and accuracy.



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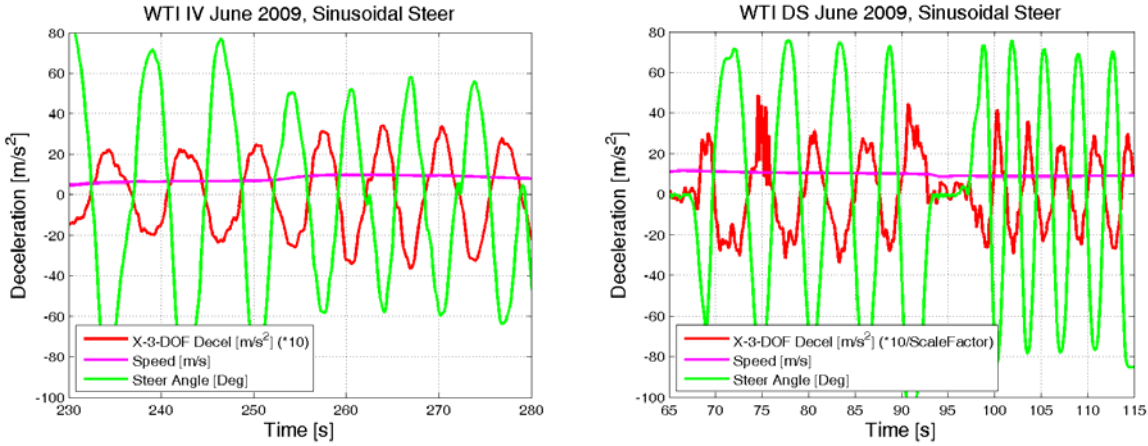


Figure 1. Lateral motion base movements (red) in response to sinusoidal steering (green) at a particular speed (magenta). The left panel shows the response of the instrumented vehicle and the right panel the response of the optimized driving simulator. The right panel shows the lateral cab accelerations divided by the scale factor to demonstrate that the lateral motions as computed from the vehicle dynamics model are close to reality.

The steering torque versus angle in Figure 2 provides a good insight into whether the torque range is realistic and whether the response time (lag) from the torque that the human puts on the steer to the steering angle is realistic. It is clear that the simulator and instrumented vehicle require the driver to generate similar steering angles and similar steering torques and that they present the driver with a similarly responsive system. The fact that the angle, torques, and lags are similar between simulator and reality shows that the steering model is representative of reality and that it further contributes to the perceived realism of the simulator.

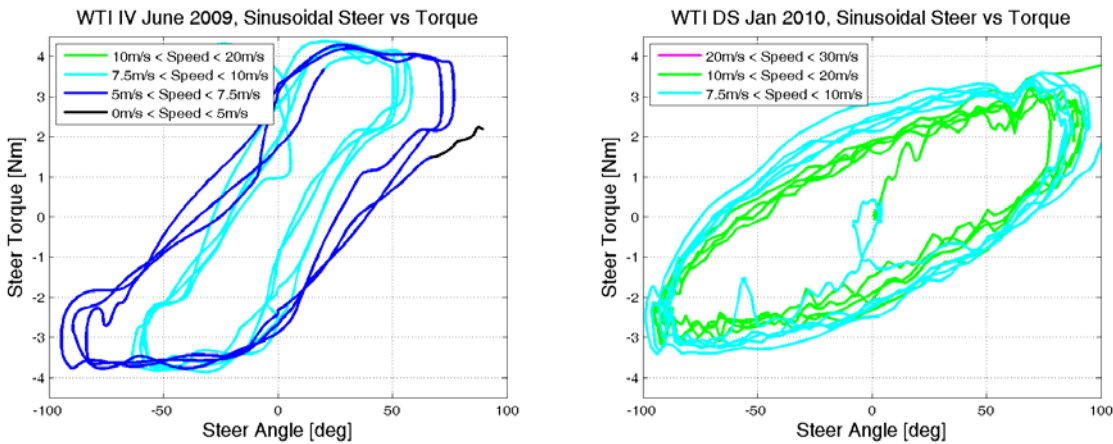


Figure 2. Steering torque as a function of the steering angles produced during the sinusoidal steering maneuvers shown in Figure 1. The left panel shows the response in the instrumented Impala and the right panel the response of the simulator. The colors indicate different speeds.

Contacts:

Professor Nic Ward, Department of Mechanical and Industrial Engineering, Montana State University, nward@ie.montana.edu
 Dr Erwin Boer, Entropy Control Inc, ErwinBoer@EntropyControl.com