



WTI Human Factors Research Facilities

Driving Simulator Optimization: Calibrating Braking and Steering Controls of 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 pedal and steering feedback component of this systematic process completed with the [WTI Advanced Driving Simulator \(WADS\)](#).

A simulator is only capable of eliciting realistic driving behavior with normal effort expended by the driver if the feedback the driver receives from the simulator is accurate (i.e. no biased or false cues), stable (i.e. correct dynamics) and fast (i.e. low transport delay). *Biased or false cues* are signals that the simulator driver perceives that are inconsistent with the overall driving experience (expectations) and thus act as distracters that degrade performance and increase workload.

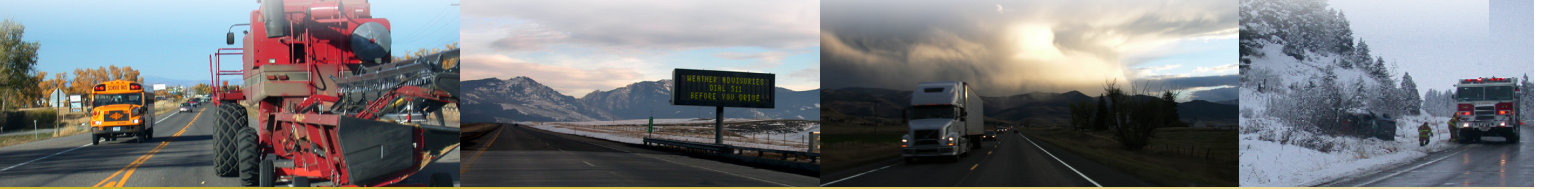
Brake Pedal Input

Braking is critical to driver safety, a topic of concern in nearly all driving simulator studies. It is therefore of paramount importance that the brake pedal feels and behaves very much like a real vehicle. Thus to assure smooth well controlled braking it is important to have a realistic heavy brake. The WTI simulator has a brake system specially designed by RTI in which cascaded springs with different stiffness result in a force profiles that approximates reality well.

To verify the match, the brake pedal was slowly depressed and released in the instrumented vehicle (left panel in Figure 1) and in the simulated Impala (right panel Figure 1). The brake force profile in the IV and the DS are similar in shape in many aspects (both show three phases of braking) as best shown by the green Michigan Scientific brake force sensor. More force is needed to initially depress the brake in the DS (50N) than in the IV (25N). This is only a minimal difference for leg muscles and has the benefit of giving the driver clear feedback that he is pressing the brake; it may in fact further avoid overshoots in braking and thus counter any transport delay effects on rendering motion with the motion base. The brake pedal in the simulator has a force feedback profile very similar to that of the instrumented vehicle.

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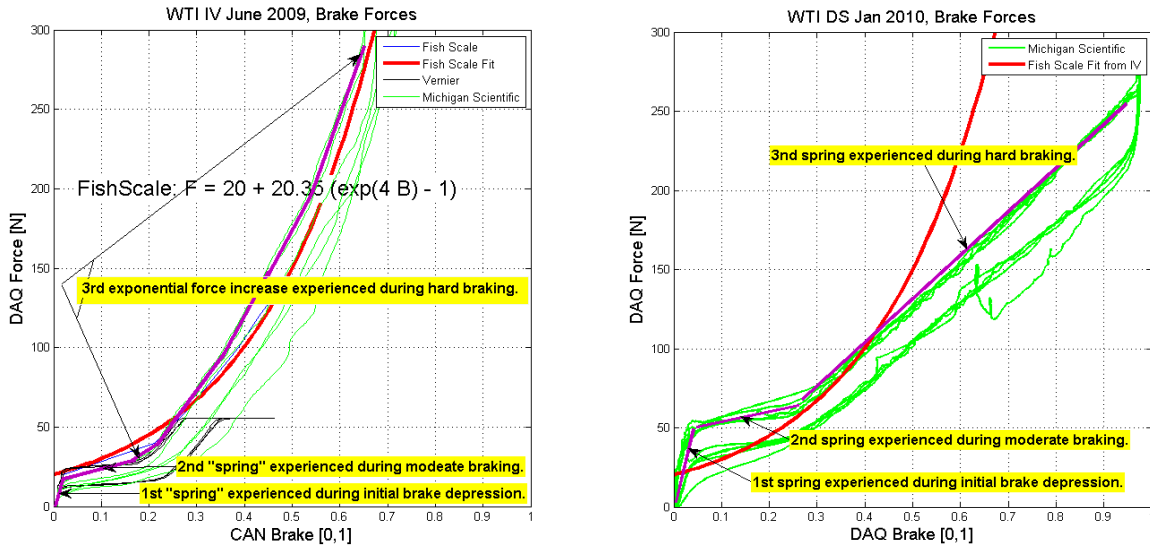


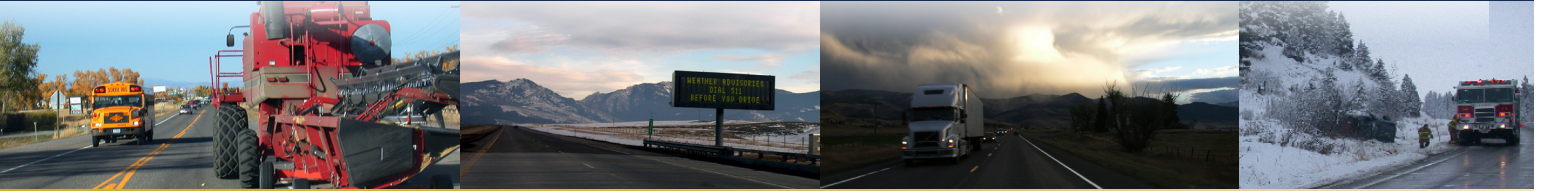
Figure 1. Brake pedal force profiles for instrumented Impala (left panel) and the simulator Impala (right panel). The Michigan Scientific brake force sensor was used in both cases. In the Instrumented Impala these results were confirmed with a Vernier Force sensor (limited to 50N) and a heavy duty fish scale (limited to 220N). The purple lines show how the slope of the relationship between brake depression and pedal feedback force are related (three linear relationships in the right panel and in the left panel two linear relationships followed by a 3rd exponential one).

Steering Wheel Input

Steering is also a critical in hazard avoidance. After such a hazard response or steering out of a sharp turn or curve, the steering wheel should return to zero in a stable fashion (i.e. without oscillation). If this is not the case, then drivers need to spend much extra effort to steer the car into and especially out-of sharp curves. For example, the driver should be able to let the steer slide through his hands when exiting a sharp curve. In many simulators the driver has to actively steer back or guide the steer to avoid oscillations. The steering model (inertia, damping, and stiffness) was tuned such that the self alignment torque from the vehicle dynamics turned the steering wheel back to zero in a fashion that closely matched what we observed in the instrumented Impala.

Figure 2 shows four key characteristics of the steering system as modeled in the WTI driving simulator through a combination of vehicle dynamics and steering system dynamics:

1. The time response of the steering wheel back to zero is faster at higher speeds. This is due to the fact that the self alignment torque is higher at higher speeds.
2. At the highest speed (lower right panel) we see a slight overshoot in steering angle similar to what was experienced in the instrumented Impala. This is due to the fact that the vehicle at that speed shows significant weight transfer which causes the dynamics of the suspension system to show up in the steering response.
3. At slow speeds, the steer does not fully return to zero or does so very slowly. This is due to the very low self alignment torque relative to the steering dynamics (inertia, damping, stiffness, and friction).
4. The torque required to keep the steering wheel at 90 degrees is higher at higher speeds. This is also due to the fact that the self alignment torque is higher at higher speeds.



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Together these four characteristics present a simulator vehicle with steering torque and stability characteristics that resemble reality and yield a vehicle that feels natural to maneuver. Their primary goal was to assure that simulator drivers would be able to use the self-alignment characteristics of the steering wheel in their control strategy in a manner similar to what they employ in reality. The steering feedback offers WTI simulator drivers the ability to use the natural return force on the steering wheel in their driving. This is especially beneficial when negotiating intersections and sharp curves and reduces the workload considerably compared to the often inherently unstable, non-dynamic, or generally weak steering systems in many driving simulators.

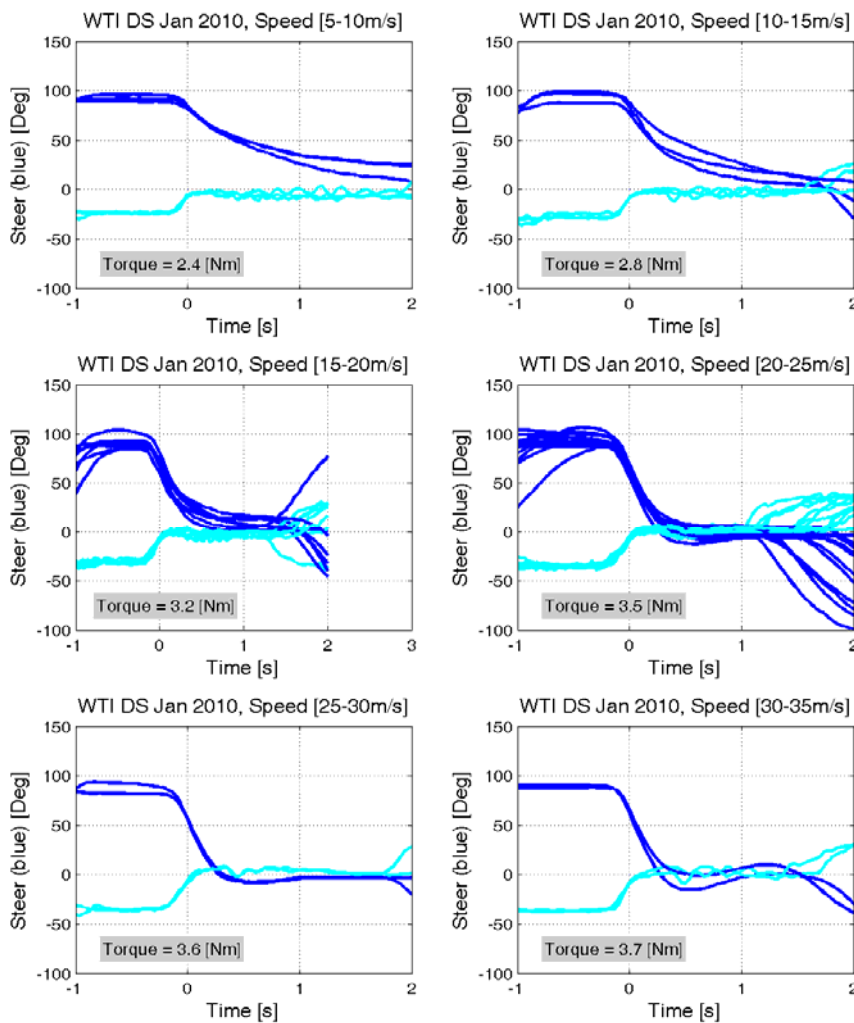


Figure 2. Response of steering wheel when the steering wheel is released from about 90 degrees at different speeds. The speed is indicated in the title of each panel. The steering wheel is shown in blue and the steering torque times 10 in cyan. The steady state torque to keep the steering wheel at 90 degrees is shown in the text inserts in the lower left of each panel. The steer is released when the cyan line begins to quickly decrease to zero. The increase in torque observed in some of the panels indicates a subsequent steering action and can be ignored.