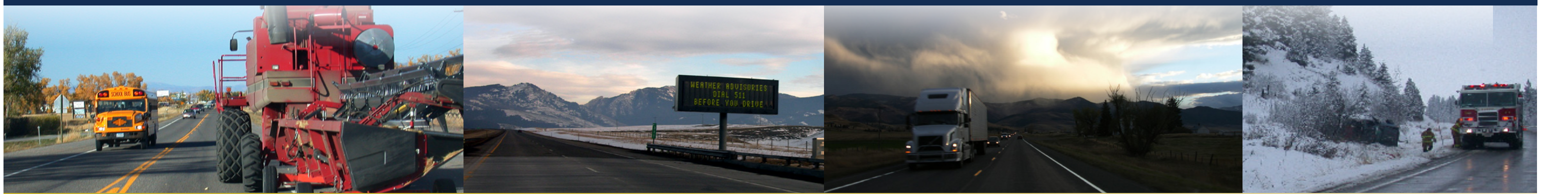


WTI Human Factors Research Facilities

Driving Simulator Optimization: Applying New Filters for Realistic Motion in Advanced Driving Simulator

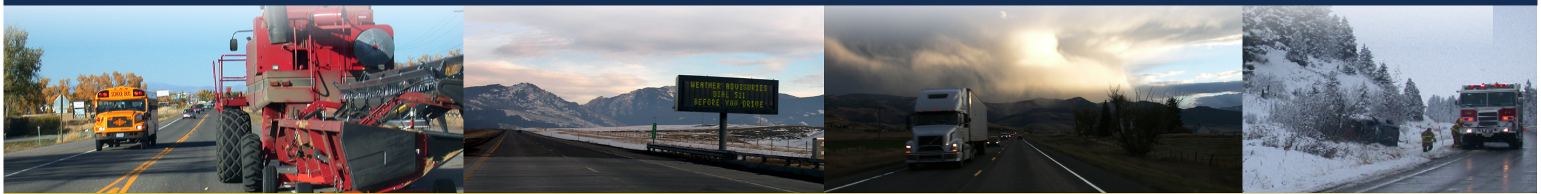
WTI has embarked on a systematic program to optimize and tune its advanced driving simulator so that it provides a realistic research and testing environment capable of yielding results that are transferable to the real world. This tuning and optimization work was completed by Dr. Erwin R. Boer (Entropy 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 motion base control 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. A motion base simulator has the potential to provide quick vestibular feedback to the driver to stabilize braking and therefore reducing the workload involved in stopping. In order for the moving base simulator to be able to achieve this it is necessary that it can provide the deceleration onset cues and a sustained deceleration cue. The onset cue should be high frequency to get the benefit from the fast vestibular system into vehicle control and the sustained cue should be strong enough for the driver to distinguish between different deceleration rates. The former is extremely important because such fast vehicle response data cannot be perceived visually while the latter is less important because the changing visual cues, auditory, and vibration cues also provide that sustained deceleration to some degree.

The optimization of the WTI motion base to assure representative excitation of motion cues was based on three criteria:

1. Sufficiently strong motion cues to get fast and clear feedback on pedal and steering movements. This enhances drivers' control stability.
2. No false motion base movements. This enhances drivers' confidence and stability because experienced motions are predictably associated with steering and pedal controls (i.e. allows the driver to build an internal model of the vehicle dynamics that he/she then uses for open loop control to boost performance and reduce effort)..
3. A feeling of sustained lateral and longitudinal acceleration. This complements the changing visual, auditory, and vibration cues and therefore will increase the overall sense of realism and therefore decrease mental workload.

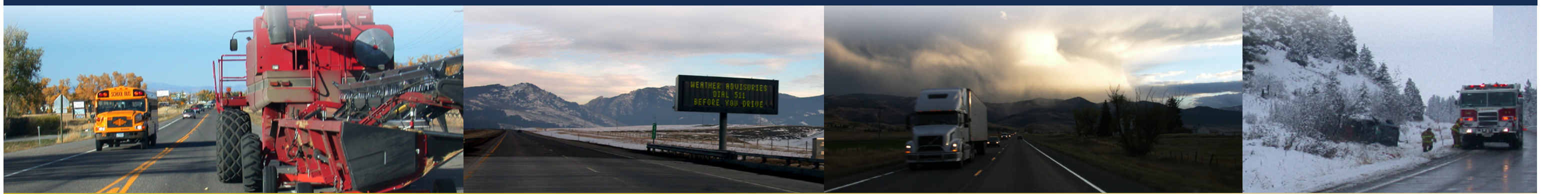
All of these criteria are met and in particular the false movements are imperceptible by most drivers (based on subjective experience of a number of internal and external people who came through the lab). The simulator offers a predictable unified sensory impression that comprises of the tightly synchronized combination of the visual, auditory, haptic, and tactile cues that enable accurate high bandwidth control of the vehicle.



The resulting motion profiles of the WTI motion base with the new applied filters are shown Figure 1. Several characteristics of the resulting motion profiles are noteworthy:

1. The final scaling for angular velocities is 0.06. This means that the motion base rolls, pitches, and yaws at 6% of its true velocity.
2. The overshoot in the opposite direction of the input for angular velocities is 20%. The false angular velocity in the opposite direction is only 20% of the angular velocity experienced in the true direction.
3. The final scaling for tilt coordination is 0.06. This means that drivers experience 6% of the sustained lateral and longitudinal acceleration through gravitational pull.
4. The overshoot in the opposite direction of the input for tilt coordination is not an issue because the filter is simply a stable low pass filter with a damping factor zeta of 1.0.
5. The final scaling for linear accelerations is 0.055. This means that the driver experiences 5.5% of the true magnitude.
6. The overshoot in the opposite direction of the input for linear acceleration is 30%. The false linear acceleration in the opposite direction is only 30% of the linear velocity experienced in the true direction.

The filters were designed such that all the scaling factors on linear accelerations and rotational angles are similar. This contributes to a rapid adaptation of drivers to the simulator. The damping factor (zeta) of 3.0 using in angular and linear high pass filters is higher than what most simulators use (i.e. classical motion cueing), but appeared to be the determining factor that eliminated false movements because it greatly reduces the unwanted overshoot in the opposite direction of the desired stimulus. That this is so can be seen from the fact that the responses of the filters in all three panels show very little overshoot in the direction opposite to the input stimulus (i.e. cyan in left panel, cyan in middle panel, and magenta in right panel). This means that simulator drivers will not readily feel the motion base return back to zero; i.e. experience unexpected motions that are inconsistent with the pedal and steering actions. The overshoot is not only small but also has a smaller slope which makes it feel less jerky and thus less noticeable. In all, the perceived motions appear consistent with control actions. To fully appreciate the motion perception, it has to be cast in the context of human perceptual limitations; a hotly debated issue these days that lies beyond the scope of this document.



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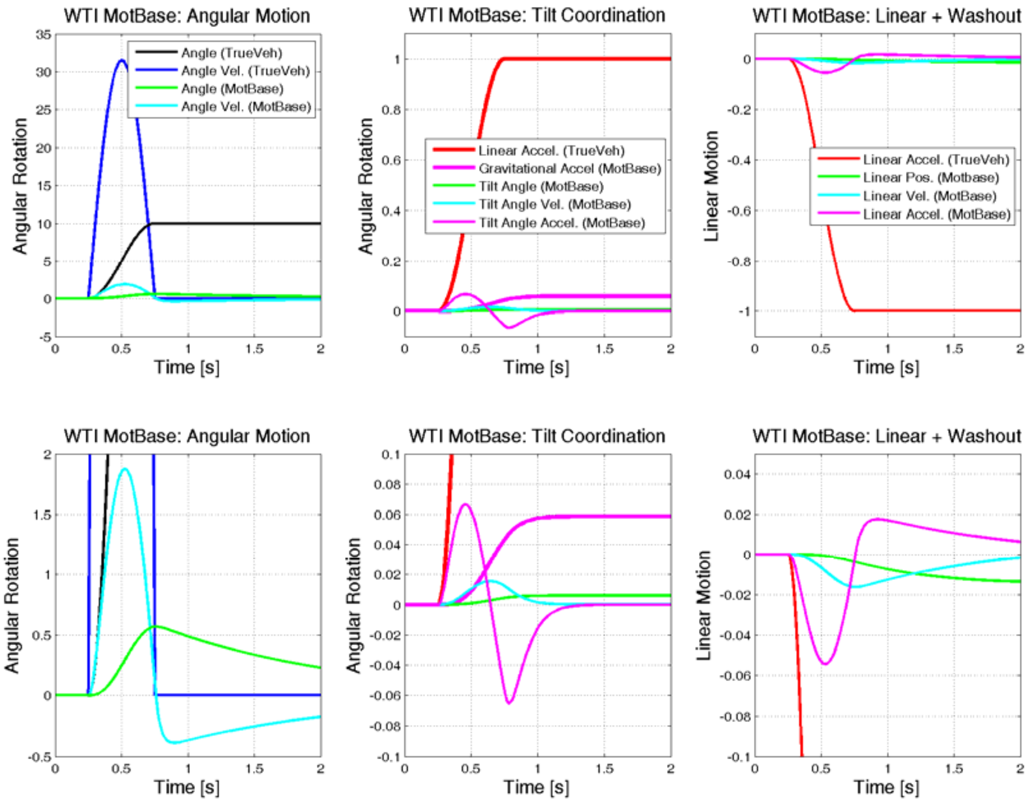

Figure 1. Responses of the motion cueing filters to a ramp input (black line in left panels and red line in middle and right panels). The input is a test signals assumed to originate from the vehicle dynamics. The left panel shows the response to a rotational velocity input. The middle panel shows the response to a linear acceleration input. The right panel shows the tilt coordination to a linear acceleration. The bottom panels are simply zoomed-in along the y-axis versions of the ones on top to better show the shape of the filter responses.

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