Using an OpenDS Driving Simulator for Car Following: A First Attempt

Abstract
This paper describes the modifications to free, open-source driving simulator software to simulate a car-following task resembling that in the NHTSA driver distraction protocol. In brief, the peak-to-peak amplitudes of the lead vehicle were sharply reduced (to 70% of the specified values) and made more uniform. In addition, the mean speed was reduced by 10 ft/s to reduce the time to get up to speed (and collect data). Finally, modifications were made to the Logitech G27 interface commonly used with OpenDS. Wooden blocks were mounted on the foot pedals to make the configuration more car-like and the accelerator and brake pedal springs were replaced with stiffer springs (Hillman #49). With stiffer pedals, there were fewer instances of excessive speeding and braking g levels were closer to those in real driving, correcting problems that commonly occur with fixed base driving simulators.

Author Keywords
Human factors, driving, cognitive workload, distraction

ACM Classification Keywords
H.1.2 [User/Machine Systems]: Human Factors
H.5.2 [User Interfaces]
1. INTRODUCTION
The design and evaluation of motor vehicles to make them safe and easy to use has been the subject of decades of work [1] and developing and specifying procedures and terms for that purpose has received some attention [2,3]. The Automotive User Interface Conference, being held for the sixth time, serves an important role in advancing the design and evaluation of motor vehicles. The cognitive workload workshop has been conducted at that conference for a number of years, with the format being presentations by those conducting research on the topic with some follow-discussion [4 5]. As many attendees have never measured cognitive workload themselves, this year’s workshop [4] will provide hands-on experience cognitive loading tasks and tasks measure cognitive load, namely the detection response time (DRT) task [7, 8] and the n-back task [9, 10]. Each of these tasks is to be practiced separately and then performed while driving, and for practicality, in a driving simulator.

2. AN OVERVIEW OF OPENDS
To support this workshop, a free, portable, and programmable driving simulator was needed. For that purpose, OpenDS was selected [11,12]. OpenDS was designed for computers running Mac OS X, Windows, Linux, or Solaris Operating Systems, and Java Runtime Environment 7 or greater. The software is programmed entirely in Java and is based on the JMonkeyEngine framework, a video game engine. The software has a high level of functionality, allowing for presenting a variety of objects in the scene, for altering the scenario (weather, traffic, traffic lights) and environment, for triggering various actions, and for repositioning the point of view. For additional details, see the OpenDS home page (http://www.opends.eu).

To run an OpenDS driving scenario, either a computer keyboard or steering wheel controller can be used.

3. DRIVING SIMULATOR CONFIGURATION
In this first attempt to demonstrate the measurement of cognitive load at this workshop, three simulators will be brought to the conference, less than desired as the attendance is expected to exceed 30. Nonetheless, this number should be sufficient to allow many of the workshop attendees to perform the tasks of interest while driving. Providing and supporting additional simulators was not feasible, especially with no budget. Each simulator will consist of a Logitech G27 driver interface (steering wheel and foot controls), and a variety of Windows laptop computers, which will be shipped to/taken to the conference. The G27’s, developed for racing games, were modified. This included removing the clutch pedal (as the simulated vehicle has an automatic transmission), and mounting wooden blocks on the accelerator and brake pedals. As a result, pedal shapes and spacing more closely resembled pedals in passenger vehicles and the brake pedal was not longer co-planar with the accelerator, so the brake pedal and accelerator could not be depressed at the same time with one foot (Figure 1). In addition, the springs in both the accelerator and brake were replaced to make them stiffer (Hillman Group #49 compression spring). The stiffer accelerator pedal spring led to fewer instances where drivers drove too fast. The stiffer brake pedal spring led to less excessive braking g levels. These two problems commonly occur in fixed-base driving simulators due to the lack of motion feedback.
On site, the laptop-G27 combinations will be connected to monitors, so that the attendees were able to readily observe the road scenes. The G27 steering wheels were not replaced with more realistic (larger) passenger car wheels to save on shipping costs and help this project be completed more quickly.

3. SIMULATING CAR FOLLOWING

The original goal was to duplicate in about a week the car following protocol in the NHTSA Visual-Manual Guidelines [13] used for studies of driver distraction. Figure 2 shows the profile for the lead vehicle. That plan involved picking 14 data points from the lead vehicle speed profile and connecting them. However, this waveform proved to be unsatisfactory. First, the speed of the lead vehicle was unrealistically variable, with speeds changing by 30 ft/s in approximately 20 s and the lead vehicle could not be followed. Also, the variability was much greater in the beginning, so the workload was not stable. As a consequence, the acceleration and braking capabilities of the lead vehicle were reduced to 70% of the original values and the difference between the three largest peaks and valleys and the mean speed were reduced by 10 ft/s.

The original approach also required a significant time (more than 40 s) for the subject to get up to speed (and additional time decelerate at the end). Typically, these two periods are not used in car following studies. To reduce the time when useful data is not collected, the mean speed driven was decreased by 10 ft/s (to approximately 70 ft/s or approximately 48 mi/hr or 77 km/hr). These changes, as well as others, resulted in a lead vehicle that could be followed, though it was challenging. More thought needs to be given as to what is an appropriate lead vehicle velocity signal for car following experiments.
In addition to creating and then revising the lead vehicle speed profile, start and finish signs were added at the beginning of the test segment and 3920 m away, and triggers were added in interaction.xml to start and end data collection. Also provided for the scenario was the carData.txt file that includes the coordinates \((x,y,z,\text{in meters})\), speeds \((\text{km/hr})\), steering wheel positions \([-1,1]\), accelerator pedal positions \([0,1]\), brake pedal positions \([0,1]\) for both vehicles, and the distance gap (meters) between two vehicles. The data are collected approximately at 20 Hz.

5. SAMPLE DATA

Inspection of the Figure 2 shows the lead vehicle speed is extremely unstable, having a very substantial range, for example changing from approximately 65 to 92 ft/s in about 20 s. The data points were manually adjusted to reduce the amount of acceleration required and to also reduce the peak values. Although the lead vehicle profile no longer matched the NHTSA profile, it was sufficient for the workshop.

Figure 3 shows a sample run with the actual lead speed proposed for the workshop as well as the speed of the subject vehicle (as driving by the first author with minimal practice). In addition, a second lead vehicle speed profile is being created in which the minimum and maximum speeds are half of those currently shown, so the lead vehicle will be easier to follow.

![Figure 3. Sample Data from Car Following](image)
6. CONCLUSIONS
The goal of this workshop was to give attendees hands-on experience with measures of cognitive workload and conducting cognitive workload data. The authors were able to assemble something for that purpose and take it to a conference in a relatively short period of time. They were able to do that because OpenDS had the road and vehicle characteristics needed for car following and data collection, though the documentation could be improved. Low cost and portability were huge plusses. However, one of the more interesting findings is that the speed profile that has been used for previous car-following studies was extremely difficult to follow, and probably unrealistic. However, this could be due limitations of the simulator used, the simple manner in which the lead vehicle speed was simulated, or the author’s misunderstanding of prior work.

References


