CRUISE: Measuring and Smoothing Driver Behavior Through Haptic Feedback

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Abstract
Fuel efficiency in driving is directly correlated to the smoothness of driver behavior. Hard acceleration, late braking, and excessive top speeds decrease fuel efficiency. I have built a system, CRUISE, to measure driving behavior and provide immediate haptic feedback to the driver to aid them in understanding their fuel usage and change their behavior in real time. The system utilizes off-the-shelf electronics to aggregate position, acceleration, and vehicle data to determine aggressive driving behavior and give real-time feedback to the driver via vibration packs attached to brake and accelerator pedals. Quasi-controlled, on-road testing was conducted on pre-determined routes to compare driving behavior changes using the feedback system. Future work looks to extend this work into longer test deployments in everyday driving usage.

Author Keywords
Driving behavior; behavior change; haptic feedback; data-logging

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces – Prototyping.

Introduction

There are three main contributors to wasted energy when driving: 1) hard acceleration, 2) late braking, and 3) excessively high speeds. By reducing the number of these events that occur during a drive, drivers can better conserve fuel [1]. To help drivers better understand their fuel usage and make positive behavior changes towards conservation, I have developed a data logging and real-time haptic feedback system. When any of the wasteful driving events occur, feedback is provided to the driver immediately through haptic vibration packs attached to the driver's pedals. This helps the driver to make quick adjustments and to understand how their actions affect driving efficiency. In addition, this information is stored locally on the system and available for later processing. Early testing has shown positive gains towards altering driver behavior and initial results reveal immediate improvements in poor driving habits when users receive in-car feedback via the vibrating pedal (as compared to control testing). Specific questions around this research for the workshop are focused on how to effectively test driving behavior change in real-world scenarios. Open questions include how to design driving routes for quasi-controlled experiments, how to test in longer term deployments, and how to analyze real-world driving data to compare the systems ability to promote positive behavior change.

Design Development

Various prototypes were developed to provide feedback to drivers about their driving behaviors and to actively prompt them to change their behavior while driving. One of the first prototypes developed was aimed towards visually alerting the driver of their aggressive driving behavior. Specifically, a fish bowl, with a fake fish was attached to the driver's dashboard. This motivated drivers to drive smoothly to protect the "fish."

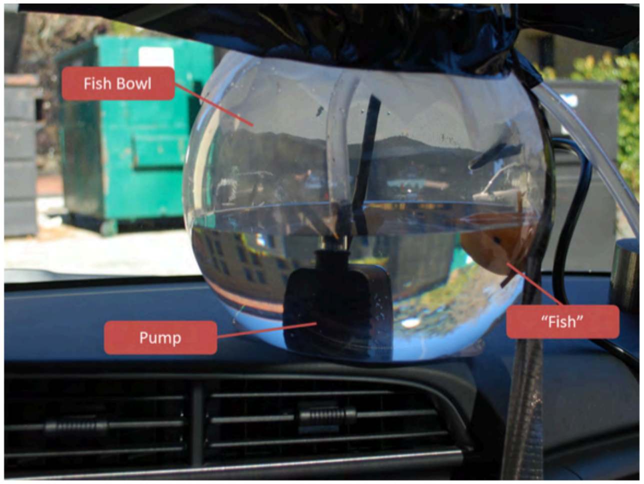

Figure 1 - Fish bowl prototype to provide visual feedback on driving behavior.

Through pilot testing with various users, it was found that the water was not visible enough to the driver. Colored dye was added, however, drivers were too visually focused on the road to pay much attention to the fish bowl. To avoid visual distraction, haptic feedback was used in another prototype. Haptic feedback has also been found to encourage fast user responses [4]. Additionally, haptic feedback has successfully been used to improve driver spatial awareness in on-road studies [2, 3]. A small piezo buzzer was attached to a driver's head to alert the driver of hard acceleration and braking measured from a simple accelerometer.

Pilot testing showed that drivers were able to easily recognize and understand what behaviors triggered the buzzer, and were not overly distracted. This prototype was further developed into a more robust sensor platform, CRUISE, which utilizes an accelerometer, GPS, and car CAN bus data. Vibration feedback was then transmitted through each pedal to directly link braking and acceleration/speed events directly to their input sources.

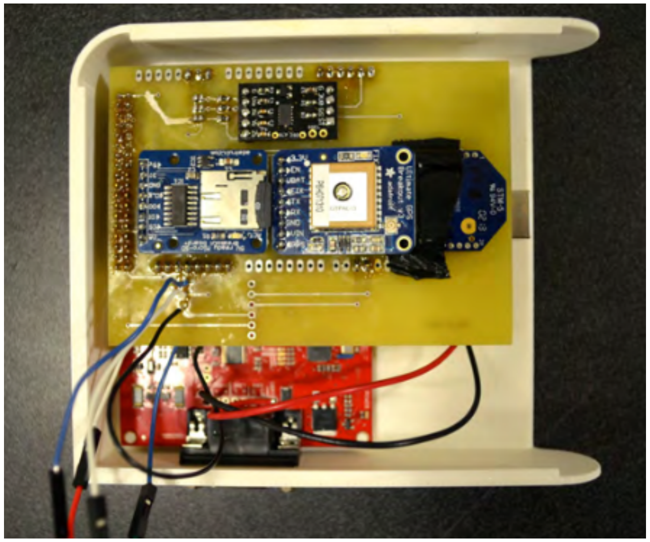

Figure 2 – CRUSE Data logging platform including GPS, accelerometer, and CAN decoder.

Figure 3 - Haptic feedback prototype.

Testing

Initial testing of the system was conducted on two-lane roads around a college campus. Four drivers drove a route with approximately 20 stop signs. This route was

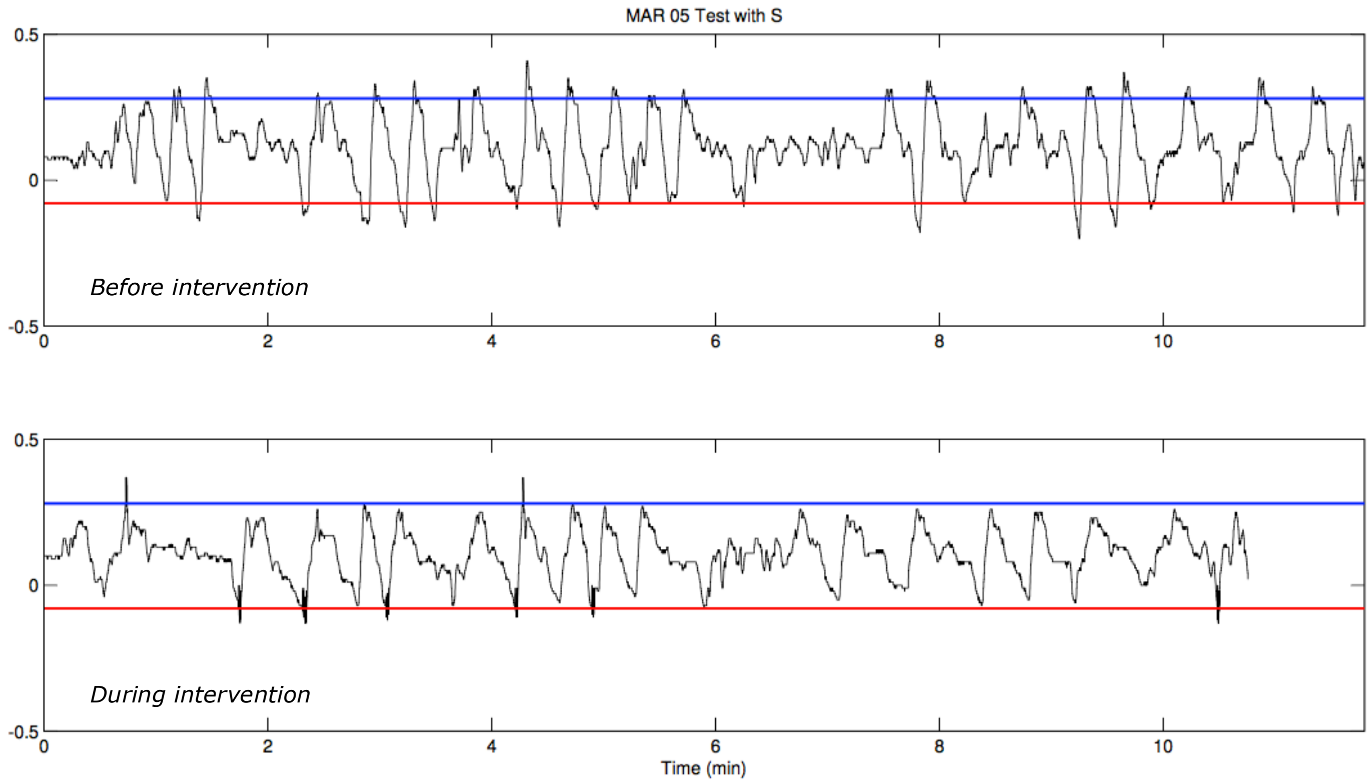

Figure 4 - Sample acceleration data comparing one driver on the same drive with and without haptic feedback. The bottom graph shows the accelerations with the feedback system, with a majority of the peaks within the threshold bounds.

used as many hard braking and acceleration events occur around stop signs. This also allowed for most stop/start events to occur around the same time between drives and reduced the number of unexpected braking and acceleration events, such as a car cut-off. This testing showed that the system helped drivers to consistently stay below set acceleration and braking thresholds, shown in Figure 4.

On-road testing was also conducted using predetermined test-drive routes, however, the number of unexpected events made the data between the no feedback and feedback conditions hard to differentiate. It was difficult to see if the system was improving driver behavior in situations when the driver could not as easily control all aspects of their driving.

Future Work

Although the system was able to help drivers during quasi-controlled driving on a pre-determined route, more work is needed to assess the system's efficacy during real-world driving usage. One area of future work involves how to determine unexpected vs. expected driving events, allowing for a better comparison of driving behavior change when behavioral interventions are used. Another open area of research concerns how to design an on-road driving course for quasi-controlled testing. Although the college campus course worked well for initial testing, more realistic but controlled events could be engineered through careful course design. Finally, research is still needed to see how longer-term deployments affect behavior change and how long the behavior change persists after an intervention is withdrawn.

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