SYSTEMS ENGINEERING APPROACH TO SIMULATOR BASED DRIVING ASSESSMENT

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INTRODUCTION

Driving is an integral part of the lifestyle in most modern industrial societies. This construct has affected where people live, how cities are planned, and how goods are transported; it permeates most aspects of everyday life. People rely on their vehicles to shop for groceries, to get work, and to maintain social interactions with each other. These needs and desires to drive extend to nearly every adult; young to old, functionally able to functionally impaired.

There are impairments that can affect a person's ability to safely pilot a motor vehicle. Two major groups that fall in this category are those with disabilities and those of older age. For either group, the main mode of local travel tends to be exclusively driving motor vehicles [1, 2]. In some cases, the physical and cognitive impairments constrain their ability to drive or even eliminate them from driving [3].

It is important to aid those with functional impairments meet their mobility needs safely and fairly. One method that accomplishes this goal is proper screening of those with declining abilities [4]. Current on-road methods are dangerous and insufficient to measure critical driving performance. This paper reviews the current and emerging methods used to identify impaired drivers and to restore them to driving. Furthermore, the application of a simulator as a substantial surrogate is proposed and its implementation discussed.

ON-ROAD EVALUATION

The on-road evaluation of an impaired driver has and continues to be considered the gold standard of driving evaluation methods [3, 5]. This assumption is reasonable given it very closely resembles the activity that needs to be measured. But there are some inherent flaws in the application of this method.

Evaluating an individual in on-road scenarios with functional impairments is inherently dangerous to the driver and the instructor, and requires a specially trained evaluator. The most important missing construct in current on-road evaluation methods is the lack of testing reactions to unexpected events. Granted that most elderly or impaired persons are aware of their deficits, and adjust their habits accordingly by driving during lower traffic congestion, or in familiar places [3]; unexpected or challenging events can still occur in these settings. It is these unexpected events where drivers must 'switch off' their automated behaviors and react appropriately with controlled behavior [6].

It would be wholly inappropriate to test individuals in these scenarios under on-road conditions, and difficult to apply consistently. Within the context of a driving simulation these types of challenging, or dangerous scenarios can be safely presented to the individual and truly assess their driving performance.

SIMULATOR EVALUATION

Vehicle simulators have been utilized as real world surrogates, often as methods of training. Two simulator based rehabilitation studies by Akinwuntan and Devos indicate a strong, positive impact on the rehabilitation and long term ability of drivers that suffered from stroke [7, 8]. Similarly, in a preliminary study by Lew et al. [9], it was shown that a driving simulator could more consistently predict the outcome of long term driving behavior than a similarly constructed on-road evaluation.

A simulator based evaluation method was developed by Khan that was constructed to evaluate neuropsychological abilities associated with driver performance and showed promise of being a valid measure of driving performance [6]. Khan also demonstrated the ability of the simulators to safely and consistently challenge the driver with dangerous or complex situations that would otherwise be unethical *in situ*, but are critical to the ability to safely pilot a motor vehicle.

DESIGN CONSIDERATIONS AND GOALS

The goal of this project is to develop a design for a driving simulator that can accurately assess the ability of drivers, especially those with declining abilities or other impairments, with a device which is relatively inexpensive and widely marketable. To develop this system the requirements must be identified and decomposed into concepts that can be addressed by technology or processes within that technology. The following subsections explore some of the various requirements for driver assessment and driving simulation.

Identifying System Requirements

After an extensive literature review of driving assessment, research on general test development procedures, reviews of existing systems, and brainstorming a list of simulator requirements were developed. The requirements can be broken into three categories: general, driving assessment, and patient interface. The more critical categories of driving assessment and patient interface are discussed below.

Driving Assessment Requirements

Many studies have explored the abilities that are needed to drive, and those that are most impacted by decline or lack of ability. The most common factors in identifying driver ability include position control, speed regulation, and hazardous events.

The most commonly important factor used in identifying driving ability is some variation of the hazardous error [5, 6, 10-13]. In all on-road evaluations reviewed, and some simulator evaluations, the measure of hazardous events was passive, waiting for such events to occur. In one simulator based evaluation an active approach was taken to assessing such events. The hazardous error is the best indicator of driving ability because it tests the driver's ability to apply controlled processes that require sustained thought to accomplish and are critical to reacting to unexpected events.

Other abilities important in gauging a person's capability to drive are the ability to control the vehicle position and speed. While strong indicators of driver performance, these abilities and their corresponding measures can provide critical information in isolating the specific behaviors or habits that lead to more dangerous situations. They also provide incites to remediation or compensation methods that would enable the driver to overcome lacking abilities.

Test constructs within each category are important to measure, but those measurements will only be valid if the virtual environment with which the driver interacts is a high fidelity facsimile of the actual environment.

Patient Interface Requirements

In simulations when the term realism is used it refers to what is known in many forms of media as immersion. Immersion is the quality of being drawn into a presented scenario; it is indicative of the willingness of a participant to accept the scenario as real. Immersion in a simulation contributes to the face and construct validity of the simulator. Additionally, various information contributing to immersion have important real world analogs that contribute to complete activity of driving. The sense of immersion in a simulator can be supported by three different categories: haptic feedback, visual feedback, and auditory feedback.

Visual Feedback

Visual feedback is the most important contributor to the sense of realism in a simulator. Vision contributes almost all the information that is critical to driving. The minimal field of view (FOV) for a driving simulator is 60º horizontal by 30º vertical [14]. This range fills the foveal and parafoveal, detail oriented, regions of the retina. To provide a fair and valid environment larger FOV views are required for maneuvers such as right and left hand turns, lane changing and merging.

Larger FOV in driving simulation can cause sensations of motion sickness. The region outside the 60º H x 30º V represents the peripheral region of vision. This region of sight provides for a sensation of motion. If the sense of motion generated here is not adequately supported by the vestibular system, motion sickness can occur [14]. This can be counteracted by providing motion simulation [15].

<u>Haptic Feedback</u>

Haptic feedback in driving simulation is utilized in a variety of manners: through controls (steering wheel and pedals), and vehicle motion.

Haptic feedback in vehicle controls, especially in the steering wheel, provides the driver with the feel of the road. It provides important information while turning. It also allows the driver to gauge the road condition by feeling slipping due to ice, loose gravel, et cetera.

Applying motion in the simulation is tied to several other requirements as mentioned in the previous section. Not only does motion feedback play a role in preventing motion sickness in drivers it also provides the driver with various motion cues that are generally expected while driving: accelerations and decelerations due to starting, stopping, and turning. Various research groups utilizing fixed base simulators have observed drivers having vehicle speed control difficulties due to the lack of motion feedback [6, 13].

SYSTEM CONFIGURATION

Considering the previously discussed requirements, an initial system configuration has been developed, see Figure 1. Gruening suggests there are four subsystems included in a simulator. They include 1) physics simulation, 2) environment simulation, 3) feedback system, and 4) input system [14]. This is an apt decomposition of a simulator into subsystems and will be used as the starting point of the system definition.

The physics simulation has to be able to adequately model the dynamics of a vehicle, the nature of the road surface, and their interaction. This subsystem must interface with the all the other subsystems. The input system will deliver driver interaction data. Then the

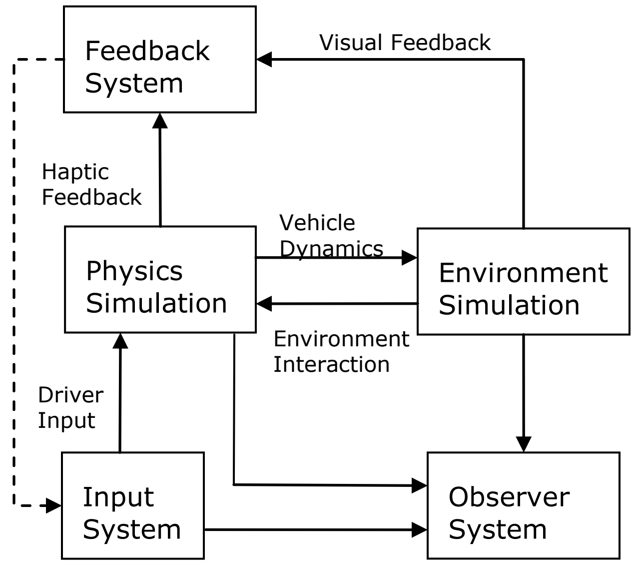

Figure 1: Simulator Expressed in Subsystems

calculated dynamics will be used as input to the environment and feedback subsystems.

The simulated environment must include other vehicles, pedestrians, buildings, weather, traffic control elements, et cetera. This subsystem interacts with the feedback and physics subsystems. The environment subsystem will provide the visual portion of the feedback system, and provide collision, road condition, and other similar information to the physics subsystem.

The feedback system will provide various forms of interaction information to the user of the driving simulator, including haptic, visual, and auditory elements. The feedback subsystem interfaces with all the other subsystems. The environment and physics subsystems provide various inputs to this subsystem. There is also an implicit connection to the input subsystem as steering control can also be an avenue for driving feedback.

The input subsystem is directly in contact with the user and is used to input steering, acceleration, and braking information into the physics subsystem. As mentioned previously, steering is also used as feedback.

The only addition to the previously mentioned subsystems would be an observer subsystem. In this subsystem the operator would be allowed to actively monitor the driver's behavior, and the behavior of the driver could be recorded, and scored within the context of the given scenario.

Now that the conceptual construct of the system has been developed, the physical layout of the system must be considered. The concept of this layout is presented in Figure 2. Each of the previously presented subsystems is represented in by their various components.

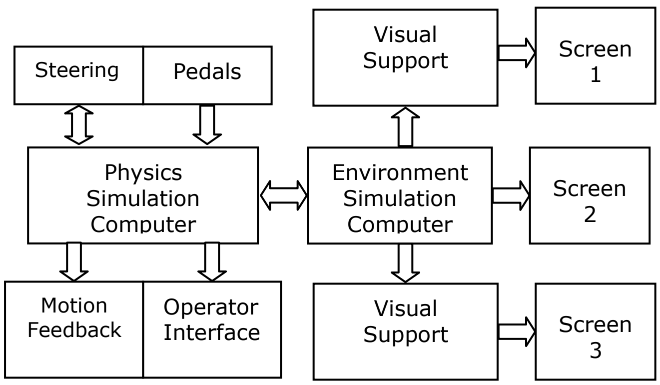

Figure 2: Physical Layout Concept

The input subsystem is represented by the steering and pedals blocks. As the arrow indicates there is information transfer between the steering block and the physics block, this indicates that the steering apparatus is not only a control but a form of feedback as well. Other components belonging to the feedback subsystem include the motion feedback and the screens used for image generation. The visual support computers enable the visual feedback by the information generated at the environment simulation computer. The dynamics of the car are generated at the physics simulation computer this device would serve as the connection point for the operator interface.

CONCLUSIONS/FUTURE WORK

The requirements of the system have been identified and decomposed into subsystems and some of their primary components. The continuing work of this project will include the identification of the specific technology that can be utilized to meet the requirements. That process will be followed by the integration of that technology and the development and testing of the evaluation construct.

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