A3B06: Committee on Simulation and Measurement of Driver and Vehicle Performance
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Simulation and Measurement of Driver and Vehicle Performance

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This paper gives a brief review of the state of the art and future potential in technical areas of interest to the Committee on Simulation and Measurement of Driver and Vehicle Performance. These technical areas are associated with vehicles and vehicle operators and include simulation, modeling, measurement, and instrumentation. Technology in the core areas of electronics, computation, processing, and sensors has been advancing, and costs have been declining rather dramatically in the last decade, and this trend shows no sign of abating in the near future. These technology trends have, in turn, dramatically increased the capability and decreased the cost of applications in simulation and instrumented vehicles. Increased capability of desktop computers and workstations has also permitted a significant increase in the amount and detail of computer modeling and data processing that can be undertaken. This paper will summarize various applications and their future trends as we enter the new millennium.

SIMULATION

National Advanced Driving Simulator (NADS)

The National Highway Traffic Safety Administration (NHTSA) is using high-end technology to develop a driving simulator that will rival the most sophisticated aerospace device and that will represent the premier simulator application in the next decade. NADS will advance highway safety through a better understanding of the complex interaction among the driver, the vehicle, and the roadway environment, particularly during impending crash situations. Rather than using expensive test tracks, trained test drivers, and potentially expensive test vehicles, NHTSA will provide itself, academia, and industry researchers with a national facility to conduct studies using drivers from the general public riding in real vehicles in a virtual driving environment. To do this, the NADS will provide accurate, high-fidelity, correlated driving cues to immerse participants in a realistic driving environment. Subjects will drive the cabs of real vehicles selected from four typical vehicle types currently in production: a large family sedan, a sport-utility vehicle, a small family sedan, and a heavy truck. NADS is nearing completion and is expected to be deployed in mid-2000 at a facility located at the University of Iowa.

An artist's conception of the current NADS configuration is illustrated in Figure 1. The cab controls and displays will be identical to those of production vehicles and, through computer control, vehicle dynamics will be used to supply control feel feedback associated with driver control actions or vehicle motion. Vehicle dynamics computers will enable drivers to experience vehicle motion in a total of nine degrees of freedom to provide accurate haptic driving cues. This motion will be complemented by correlated 360-degree visual and audio cues, also under computer control. The photorealistic visual scenes provided by a high-end Evans and Sutherland image generator will include moving vehicles and pedestrians to complete the driver's perception of being immersed in urban and rural traffic situations. The audio system will provide appropriate sounds internal and external to the cab, including Doppler and side-to-side directional effects.

The design of NADS allows for a wide range of potential applications, including new cockpit intelligent vehicle systems (ITS) technology, control and instrument layout, vehicle control systems, driving while impaired, and problems with novice and elderly drivers. NADS virtual driving experience is intended to be a complete sensory environment that will allow drivers to be immersed in realistic tasks under real-world motivations. The simulation environment will permit roadway hazards and traffic conflict situations to be

FIGURE 1 Artist's conception of the National Advanced Driving Simulator.

presented that are impractical to control on test tracks or public roads but can be experienced in the NADS without safety consequences in the event of accidents.

Moderate- to Low-Cost Simulation

A range of driving simulations are based on silicon graphics and high-end PC technology (*1*,*2*). The graphics capabilities of these systems have increased dramatically in the last decade, permiting visually complex scenes including texture. Most of these devices have a fixed base and include relatively restricted fields of view, although virtual reality head-mounted displays allow for a low-cost wide field of view. Relatively low-cost electromechanical six-degree-of-freedom limited-motion systems are now available that allow for moderately priced moving-base simulations (*3*).

New graphics accelerator cards for PCs permit the deployment of quite low-cost aeronautical and driving simulations with very realistic visual displays. This technology has been used for simulations of parachute handling and table top driving (*4*), and for animation and visualization systems to illustrate proposed project designs (*5*). PC-based systems are capable of presenting relatively high-fidelity visual, auditory, and control-feel sensory feedback to the operator. Continued technology improvement and decreasing costs are anticipated over the next decade. As capability increases and costs decline, increased use of simulators is projected for applications such as training and licensing of novice and professional vehicle operators.

VISUALIZATION

Given increasing capabilities and decreasing costs of three-dimensional (3D) computer graphics, visualization is now commonly used in a number of fields to review designs and proposed developments, portray aeronautical and highway traffic flow, and reconstruct accidents, as well as other applications. At the recent TRB 3D in Transportation Symposium and Workshop (*6*), several trends in visualization and animation were apparent. First, the use of moderate to low-cost PC platforms is increasing. A second trend is development of simplified 3D visual database modeling procedures that are reducing the effort required to produce visualizations. A third trend is the ability to move through models in real time so that viewers can determine their own trajectory and point of view in reviewing proposed designs and developments. This last development is akin to real-time simulation, as discussed earlier, and portends the merging of visualization and simulation technology.

INSTRUMENTED VEHICLES

Instrumented vehicle research has benefited greatly from developments in sensors, electronics, and processing. A significant recent trend is to make instrumentation as unobtrusive as possible. For example, the University of Iowa has developed two fully operational human factors field research vehicles for conducting ITS and driver performance research. A 1995 Ford Taurus station wagon and a 1998 Ford Expedition were heavily modified to incorporate a completely hidden instrumentation package. The goal and strategy of the Iowa human factors team were to build research vehicles that do not appear to be different from normal vehicles. All wiring and cables are hidden in the ceiling and floor panels. The vehicles contain four pinhole cameras that cover the forward-roadway, eye, over-the-shoulder, and center-lane-tracking views. The cameras are mounted so that they are hidden from the driver's view. An eye glance camera is positioned inside the rearview mirror, and the forward roadway camera is positioned directly behind the rearview mirror and is completely occluded from the driver. The lane-tracking camera is mounted inside the housing of the outside left rearview mirror and is completely hidden from view. The over-the-shoulder camera is mounted inside the dome light. In addition to the hidden cameras, the instrumentation suite contains other hidden sensors, processors, and recording equipment, including a lateral-longitudinal accelerometer, accelerator pedal and brake sensors, forward- and rear-looking laser range finders, PC videocassette recorder, video quad multiplexer, Pentium II laptop, and a 750-watt power inverter. Electronic data are integrated and recorded on a laptop PC at 12-bit resolution, and the camera video is recorded using MPEG3 compression on the hard disk. Real-time vehicle performance information (e.g., vehicle speed and acceleration) is superimposed over the video.

A similar unobtrusive instrumentation approach has been taken with the NHTSA Data Acquisition System for Crash Avoidance Research (DASCAR) and a relatively inexpensive derivative portable system (Micro DAS), which can be mounted in virtually any vehicle with relatively little effort (*7*). The Micro DAS has been installed in subjects' own personal vehicles and has a full-motion video compression recording system that can collect over 22 hours of data. Data collection can be triggered manually or based on events defined by the researcher. The Micro DAS allows information on driver behavior and performance, vehicle performance, and roadway environments to be recorded in situ in the real world during personal driving trips without the involvement of research personnel. Subjects check their vehicles in periodically for data recovery, which are then analyzed to reveal the real-world behavior of drivers.

FHWA has sponsored the development of a Human Factors Field Research Vehicle (HFFRV), which is designed as a self-contained laboratory for studying driver behavior in the real world (*8*). The vehicle is equipped with a reconfigurable control-display console that will allow research on different in-vehicle information systems. A variety of sensors and significant on-board processing are included to control the onboard systems and to collect a range of vehicle and driver behavioral data.

Other recent instrumented vehicle research has employed eye movement measurement systems (*9*), as shown in Figure 2. Examples of other research vehicles are found in the technical literature. Martini (*10*) recently instrumented a fleet of vehicles with a new data acquisition system. Robinson (*11*) plans to investigate the ride and handling qualities that buyers like best and then replicate these qualities with instrumented test vehicles. Thomas (*12*) describes how the use of electronics has altered the way automotive engineers design automobiles. He concludes that the vehicles they build are becoming personal computers on wheels. Buchholz (*13*) describes the methods applied by Chrysler, Ford, and General Motors in operating their instrumented vehicles on their proving grounds, and Ashley (*14*) describes recent developments in intelligent vehicles and automated highways.

DRIVER AND VEHICLE MODELING

Interactive Highway Safety Design Model (IHSDM)

FHWA has undertaken a multiyear project to develop IHSDM, which is a set of software tools, to analyze candidate highway geometric designs from a safety standpoint (*15*,*16*). IHSDM will include a computational driver-vehicle model that will simulate the moment-

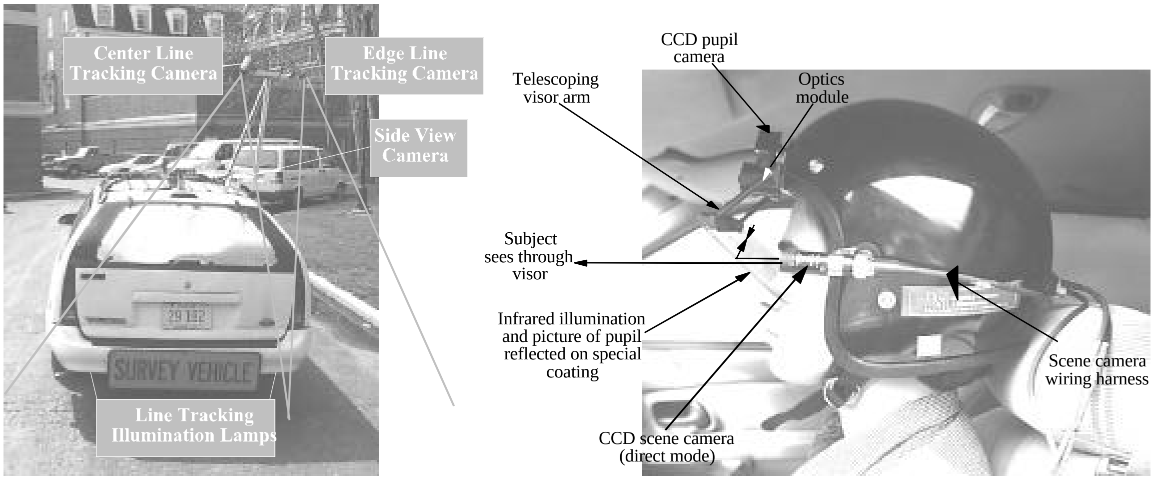

FIGURE 2 Instrumented vehicle with eye movement measurement (9).

to-moment actions of a single driver-vehicle unit and will be used to predict drivers' speed and path choices as a function of road geometry. Issues related to driver modeling in this context—especially speed decision—are discussed elsewhere (*17*,*18*). Vehicle dynamics models have also been upgraded for use with the IHSDM (*19*). Object-oriented programming is widely used in software development and has also been applied to IHSDM to define traffic and highway classes and objects (*20*). This development could lead to a rich library of reusable objects that could find applications in other areas of simulation.

Behavior of Vehicles and Operators

Vehicle operator modeling has been and will be a matter of continuing interest in regard to safety, performance, and comfort and convenience. Building on several decades of modeling development, ideas such as optimal control and preview (prediction) were introduced and have been discussed by Levison (*17*,*21*), and these ideas have been incorporated into IHSDM driver model. In 1998 this committee sponsored a session at TRB annual meeting that resulted in six papers covering areas such as driver-vehicle system performance in the longitudinal control of headway range, an interactive highway safety design model, driver mental work load, visual information processing, and human movement and posture (*22*). Two years before that, the committee sponsored a session in which driver modeling in general, as well as microscopic aspects of traffic flow, were discussed. [A compendium of traffic flow information and modeling was published in 1991 (*23*).] Recently, researchers in cognitive psychology have combined cognitive behavior models with a perception and motion model to produce a simulation known as ACT-R/PM (*24*). Significant strides have also been made in kinematic and biodynamic modeling, which is useful for the design of work spaces for ride- and crashworthiness (*25*).

Given these steps in modeling and understanding, accompanied by technological advances in driver assistance systems, future operator models may include sections representing limits on working memory, situation awareness factors and associations, decision making, rule selection for identifying the desired dynamics, skill level and experience with the vehicle, and supervisory behavior. This challenge may appear to be unrealistically complex now, but the information revolution should facilitate the communication of the techniques, concepts, and creative ideas as needed to achieve models for emulating vehicle operator control, guidance, and navigation in performance- and safety-related situations.

CONCLUDING REMARKS

Dramatic changes are occurring in the core technologies that enable the areas of interest to the committee. Advances in sensors, electronics, processing, storage capability, and computational algorithms are allowing significant advancements in simulation, vehicle instrumentation, and operator and vehicle modeling. These trends appear to be sustainable for the near future, so the first decade of the new millennium should bring significant progress in capability and reduced cost in achieving given capabilities. These trends portend expanded applications: wider utilization of simulation in training and certification; use of instrumentation and data collection for research, monitoring, and forensic analysis; and more complex and veridical models of operators, vehicles, and systems (operator/vehicle/environment) to be used in design, prediction, and forensic analysis. Given these technical trends, it behooves us to continue research on operators, vehicles, and environmental conditions that will lay the foundations for realizing the full potential of simulation and instrumented vehicle and modeling technology.

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