The Evolution of a Virtual Reality Driving Simulator: From Law Enforcement Training to Research and Assessment

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A virtual reality driving simulator (VRDS) being used by police agencies is presented. The evolution from police training to driver assessment and research is discussed. This presentation will review automated data collection capabilities of the latest VRDS produced by Time Warner Interactive Simulation Products for use as an assessment tool for the disabled.

Background

With low cost microcomputer technology becoming more available, a wide variety of virtual reality driving simulators (VRDSs) have been developed. Such technology has a range of uses, including training for emergency vehicle operations and procedures, assessment, licensing, driver education, and research. Further, for the disabled driver, the VRDS may offer a flexible, safe environment to learn or relearn to drivewith adaptive controlsbefore actually getting on the road. Two predominant systems exist. The "classic" style of virtual reality system, with a head mounted display (HMD) is actually rare in the driving simulator arena. An approach to a fixed-based virtual reality/driving simulation system that did use an HMD was recently demonstrated by Levine and Mourant (1995). In this approach:

> A seated user views a computer-generated model of a vehicle interior and surrounding road environment through a head-mounted display (HMD). The HMD consists of a liquid crystal display (LCD) attached to a six degree-of-freedom head tracking system. The displayed graphics respond to the motion of the user's head. As a result, the user has a 360-degree view of the interior and exterior surroundings, and feels "immersed" in a computer-generated environment. The user "drives" the simulator with automobile controls, which include a steering wheel and pedals for acceleration and braking.

While such a system offers flexibility (e.g., little display hardware needed, variety of interiors available) the system as presented has limitations. Unlike other display approaches, the HMD device itself may be somewhat cumbersome and uncomfortable, especially for prolonged use. In addition, as with other driving simulators, the frame update rate may decrease dramatically, especially as the number of objects or vehicles in the scene increases. Further technological advances promise to allow more improvements in such HMD systems.

Another approach, known as the "cab environment virtual reality system" (Flack, 1995) seems to be the predominant system thus far. A wide range of such driving simulators exist including single-screen, non-motion based systems starting in the $40K - $80K range on up to full, motion-based systems in the multi-million dollar range. With the recent advances in high-resolution graphics, software, and hardware, powerful desktop computers are now being used for fixed-based driving simulators. While fixed-based simulators have some performance limitations, as compared to large, full-motion simulators, they are now being used for a variety of driving applications.

Many such cab-systems have been introduced over the last few years. For instance Allen, Rosenthal, & Parseghian (1994) describe a flexible single-screen, PC based simulator. This has been used for a variety of research including the measurement and screening of driver psychomotor and cognitive behavior, evaluation of seating and control display layout, and as part of a study on the assessment of truck driver fatigue.

Recently, a new "standardized" VRDS called A.M.O.S. (Advanced Mobile Operations Simulators) has entered volume production for use in police emergency response driver training programs across the country. Such a device provides police agencies with a valuable alternative to expensive and dangerous training on a specially prepared high speed track. Instructors can safely assess officer/trainee understanding of proper police procedures and driving policy in real world situations at low cost and no risk to life and property. One important and unique feature of this VRDS is the ability to "link" several units together into the same virtual experience. Using the VRDS in the "linked" mode, several officer/trainees can participate in a multi-vehicle tactical operation, such as responding to a robbery in progress or high speed felony pursuit. Officer/trainees can be evaluated on their ability to maintain control of their vehicles, follow appropriate policy and procedures, maintain proper radio communications, and exercise sound judgment and decision making under stress.

This VRDS, called A.M.O.S. , was first developed in 1993, evolving with the guidance and input of various police training agencies around the country, including three pilot sites in California. This product is revolutionary in many ways. As previously mentioned, these simulators can be "linked" to provide an interactive experience for group training to develop tactics and teamwork. Additionally, this VRDS includes a unique "scenario authoring" mode that enables trainers to develop specific training experiences that support the learning objectives of their curriculum. This "scenario authoring" capability enables instructors to tailor training scenarios to their immediate needs and to easily modify these scenarios if mandated by changes in state or federal law or revisions to local agency policy. Since these "scenarios" are recorded on standard floppy disks, local agencies can collaborate by exchanging scenario files and state wide agencies can establish training standards through wide dissemination of an approved scenario library.

Numerous police agencies, both large and small, in California, Ohio, Massachusetts, Illinois, Iowa, and several others are currently using five and eight-screen versions of the simulator for training exercises emphasizing the coordination of tactics, reinforcement compliance with organizational policy, and dispatcher instructions (Time Warner, 1994). In this application, up to eight simulators can be connected to facilitate full-pursuit interaction with fellow officers "on the road." Another use of this system is currently being used by the Association of Bay Area Governments (Garcia, 1995). This portable training facility (a 48-foot trailer) holds four simulators which are used for police training at several sites around the Northern California area.

Simulator Configuration

The A.M.O.S. driving simulator is equipped with standard vehicle controls, including turn indicator, column shift, seat belt, and steering wheel surrounded by a 5 CRT screen configuration that produces a 225-degree panoramic field of view outside the "vehicle." Each of the 25-inch screens has a resolution of 512 X 384 pixels. The frame update rate varies from 12-20 frames/second (12-20 Hz) depending on how many vehicles are in the scene at any one time. A series of microprocessors compose the system including a sound microprocessor which generates realistic auditory feedback (e.g., tire skidding sounds when stopping or turning too sharply). According to Time Warner Interactive (1994):

> The simulator is controlled by a network of microprocessors which update the simulated vehicle's position and the driver's viewpoint. A mathematical model of vehicle dynamics gives the simulator its realistic response to road conditions and the driver's controls. Typical vehicle dynamics characteristics such as acceleration, suspension reaction, braking and cornering forces are included in the model calculations. The driver's "hands-on" feel of the vehicle is simulated by physical forces transmitted through the steering wheel. Road and engine vibrations are additional forms of physical feedback (transmitted through the steering wheel and seat).

The simulator recreates both visual experience and the "feel" of driving an automobile. The simulated vehicle is operated within a computer synthesized interactive three dimensional "universe" which is displayed from the driver's point of view. All the objects contained in the synthesized universe are represented as three dimensional solid objects which can be viewed from any angle, such as when driving around the rear of a building. Also any impact with a solid object, such as with another vehicle, will result in a "collision." The shapes of these objects have been designed to be easily recognized and generically representative of real world objects such as office buildings, houses, and road signs. Objects which will interact with the driver (cars, bicycles, pedestrians) can be programmed to appear. The "vehicle model" algorithms include such factors as suspension spring coefficients and dampening factors, drive-train torque curve, tire patch dynamics, vehicle mass, and center of gravity. Although the simulator itself does not move, the tactile, visual, and aural feedback create a compelling illusion that the driver is behind the wheel of an actual vehicle. If the wheels encounter a bump in the road, such as a curb, the forces of the bump are transmitted through the steering linkage and a jolt in the steering wheel is felt.

VRDS Development and Uses

Another group using such technology is the research community. From a progressive point of view, Peck and Wachtel (1993) discuss the possibility of using a driving simulator as part of the future licensing process. They introduce advantages of simulation technology including: 1) increased standardization of tasks demands and scoring, 2) increased precision and sensitivity of scoring, 3) inclusion of hazards and accident avoidance situations, 4) inclusion of a wider array of drive task demands, including freeway driving and driving under reduced illumination, and 5) manipulation of difficulty level of the task demands. Further, Peck and Wachtel describe a three-screen driving simulator which has been used for experimental purposes.

This VRDS continues to evolve with the input and guidance from police agencies (and other users) around the country. Research related to driver assessment is being done by a numerous researchers (e.g., Ohio State University, San Jose State University, AAA Traffic Safety) using similar evaluation techniques (i.e., "subjective" assessment of driving behavior using checklists) for a variety of research needs. Such research is quite promising.

For example a 1991 study, using the above mentioned simulator, by Szlyk, Severing, and Fishman (as cited in Janke, 1994) found that visual function measures combined with simulator indices (i.e., lane deviation, brake pressure, reaction time) accounted for a large amount of the variance in real-world accidents and in simulator crashes. Szlyk, Alexander, Severing, & Fishman (1992) evaluated the driving performance of subjects with retinitis pigmentosa (partially blocked vision) and found that visual field loss is a primary correlate of automotive accidents in individuals with retinitis pigmentosa. Cox, Gressard, Quillian, Westerman, & Gonder-Frederick, (1992) tracked lane position, yaw, brake and gas pedal pressure, and time on and off the road which was collapsed into the general categories of steering and speed control. This study investigated the effect of drinking on one's choice to drive and found that legally intoxicated subjects were still willing to drive 33% of the time and that their performance was worse as compared to a control group. Szlyk, Fishman, Severing, Alexander, & Viana's (1993) study used this simulator to evaluate driver performance of subjects with central vision impairment as compared to a control group with normal vision. They found that the group of central visual subjects showed longer braking response times and a greater number of lane boundary crossings than the control group.

More recently, updated versions of this driving simulator have been used for various purposes. For instance, Olsen (1995) used a five-screen version in conjunction with an established hospital occupational therapy driving evaluation program to compare driving assessment scores on-the-road to scores collected while driving the simulator. Other experimental research which has used this system includes studies on sleep deprivation, drugs and alcohol, Alzheimer's and diabetes disease, and older drivers.

Data Collection

To assist the potential users (e.g., police agencies, researchers, and others) of this technology, objective, automated data collection capabilities exist with the driving simulator, which have recently been made available. In fact, for one researcher investigating the effect of certain drugs on driving and attention, a customized data collection program was developed to enable recording of small changes in behavior (e.g., in lane deviation behavior). Now, such ideas are being expanded to be usable by other potential users, such as the disabled/driver assessment community.

For instance, researchers are coming forward with new research proposals for future research. This research may utilize expanded data collection requirements and automatic data collection and abilities as needed for researchers to allow a more objective and quantifiable assessment.

Such simulators can now be used for the assessment and rehabilitation of the disabled driver. With a growing number of disabled drivers on the road, a VRDS provides a safe driving environment for both the evaluator and the patient. While a VRDS may not be a substitute for an on-the-road examination, it is a valuable tool for evaluating and training purposes. Driving evaluators can use the VRDS to judge the ability to drive before the on-the-road evaluation.

Assessment of Patient Capabilities and Needs

A VRDS placed in a hospital or rehabilitation environment can provide a patient the chance to be assessed, perhaps during recovery. Since mobility is a major factor in most patient's lives, this could provide the patient with a safe and positive "driving experience" which could be very important toward future rehabilitation therapy.

The VRDS can provide a self-paced retraining experience in a non-threatening manner. It provides an environment which allows repetitive tasks to be performed without a therapist being present. Performance can be easily recorded and reviewed by both the patient and therapist.

The VRDS provides the versatility to customize the assessment and rehabilitation process for each individual patient. Assessment can be performed either by direct observation of the disabled driver's performance or by analysis of the data provided by the simulator or a combination of both. Data such as the position, velocity, and acceleration of the vehicle and the driver's operation of the vehicle's controls can be plotted with respect to a variables such as road position or scenario duration. A computer provides the capability to collect and analyze specific parameters generated by the simulator during training or testing exercises that can be used to evaluate driver performance. The steering wheel movements, brake pedal pressure, and throttle application are just a few of the typical driver control inputs which can be monitored. The timing between specific events in the simulation can be stored, measured and replayed on the screen for student self-evaluation or instructor analysis. The capability exists to plot performance in an easy-to-see format.

The evaluator can design and program scenarios which will look for specific deficiencies in the disabled patient. Skills and abilities such as scanning ability, hand position, turn signal use, reaction time, judgment and attention, and ability to brake or accelerate smoothly can be assessed.

Programmability

Numerous scenarios can be developed to include multiple lane streets, one or two way streets, two or four-way stops, parking lots, traffic lights, and a variety of signs, pedestrians, and vehicles.

Evaluation and Familiarization of Adaptive Controls

Since the steering column, gas and brake pedals are positioned as in and actual vehicle, adaptive controls can be placed on the VRDS for evaluation to ascertain which controls are appropriate to the needs of the patient. With this established, the patient may be able to practice on the VRDS before going out on the road.

Conclusion

With an evolution from police training to a variety of research and practical uses, the VRDS may be a helpful interface between the patient and the real world driving environment to achieve the patient's ultimate goal of mobility. It may help to identify the deficiencies of the disabled driver as it applies to the "whole" driving task and not just it's "parts." With the continual development of such technology, it is hoped that the police agencies, research communities, and adaptive/disabled driver communities will collaborate. Such collaboration will assist in the further development of virtual reality driving simulators use as an assessment tool for the disabled and other populations.

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