Development of a Linked Simulation Network to Evaluate Intelligent Transportation System Vehicle to Vehicle Solutions

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Intelligent Transport Systems (ITS) Vehicle to Vehicle (V2V) and Infrastructure to Vehicle (I2V) technologies promise significant advances in roadway safety, but the prolonged timeline for migration to these technologies suggest turbulent decades of driving safety research to come. To answer the ongoing question of how ITS based evolution of the driving environment will impact The Vehicle Fleet and the driving public, simulation based driver research will be necessary. Unfortunately, traditional single-seat simulators are not well suited to answer questions about networked ITS systems, which inherently involve multiple actors. Multiple seat driving simulators (MSDS), in which drivers interact in a single virtual environment, is argued to be the solution. Details of the ongoing development of the Real-time Multiple Seat Simulator (RMSS) at The University of Central Florida are presented, and implications of this and futures linked simulation installations discussed.

Intelligent Transport Systems (ITS), Vehicle to Vehicle (V2V) and Infrastructure to Vehicle (I2V) technologies allow the transfer of information between moving vehicles and between roadway infrastructure components and vehicles. Technological opportunities abound, perhaps most exciting of which is the potential for at-risk vehicles be identified, or indeed self-identify before collisions. By building in-vehicle systems that activate alarms or assistive automated actions, connected solutions suggest many potentials to mitigate impending destruction and loss of life. Passenger vehicle manufacturers and U.S. government agencies have been hard at work developing this potential (Misener et al, 2010). The systems currently in development will warn drivers of upcoming collisions, provide intelligent collision avoidance interventions, allow vehicles to safeguard incapacitated drivers, and more.

As straightforward as use cases for ITS technology seem, complications abound. Regulators must decide what

Fig. 1: A 'Wizard of Oz' confederate in Pod 1 closes in on an unsuspecting participant. The Real-time Multiple Seat Simulator (RMSS, pronounced 'rims') at The University of Central Florida allows multiple drivers to interact in one environment.

 DOI 10.1177/1071181312561487

capabilities are core to the mission of protecting all drivers and should therefore be mandated for broad dissemination, and which can be safely left as product differentiation points for manufacturers (Herrtwich & Radusch, 2011, Misener et al, 2010). Questions of this nature are further complicated by a slow projected rate of adoption. Penetration of ITS technology is projected to take as much as three decades (Appel, 2010). The intervening makeup of The Vehicle Fleet will be constantly changing. ITS technology will first be a rarity, then a luxury, and at last legacy vehicles will remain a dangerous blind spot in an ever more aware transportation grid. The ongoing question will be: how is the current aware vs. legacy mix of The Vehicle Fleet impacting the roadway environment and the driving public? Research addressing this problem must involve agile inquiry; rapid and concise results utilizing careful and ecologically valid analyses will be the only hope of forecasting and mitigating problems. The clarity and timely nature of these forecasts will not only allow OEMs to provide their own solutions, but allow regulators to intervene less often and to greater effect. In fact, it is likely that many of these technologies will be reactive; they will be deployed to triage loss of life in a specific statistically identified context. In this sense, future ITS technologies more closely resemble modern day software patches than classical Engineering based passive safety innovation. As such, their effectiveness will rely heavily on the quality of the data at hand. ITS technologies, more than any before them, may only be as good as the data that drives their deployment.

For the moment, participant safety issues and associated liability mean that simply putting drivers behind the wheel of ITS enabled vehicles is not yet feasible. Innovative initiatives such as the Research and Innovation Technology Administration's (RITA) Driver Clinics have mitigated these concerns by putting professional drivers behind the wheel while participants representative of the driving public rate the usability of proposed technologies from the passenger's seat (RITA, 2011). However, there is a real need to put users in direct contact with the new technology. As is often is the case when driving data collection is too risky for human participants on real roadways, simulation is an answer.

Unfortunately, the current generation of simulators have a number of problems in addressing the questions involved with Intelligent Transport Systems technologies. In fact, ITS systems represent a novel challenge for all methods of simulating roadway conditions, from macro-level modeling of traffic flow (Stanica et al, 2011) to micro-level human participant testing. Current state-of-the-art research driving simulation provides a reasonable approximation of climbing behind the wheel of a vehicle. Participants are introduced into world in which artificial intelligence combined with event driven scripting allows for stimuli comparable to what is experienced in the real world. The data gathered looks specifically at an individual's ability to perform the driving task in the face of artificially induced adversity, proposed new equipment or systems, or other novel manipulations. It is in this focus on the individual that single-seat driving simulators (SSDSs) reveal themselves as uniquely ill-suited to probe the questions that Intelligent Transport Systems raise.

ITS technology use inherently involves multiple driver scenarios; the systems that will be built upon it will inherently consider drivers as a group in order to save drivers as individuals. In single-seat driving simulation (SSDS) all drivers beyond the participant must be computer controlled models. Artificial intelligence does a good job of keeping simulated cars on the road, but in terms of realistic response to human action it is woefully inadequate. It is for this reason that every simulation package includes the ability to script vehicle movement, allowing for the laborious construction of moments of seemingly realistic behavior. AI controlled vehicles are likewise incapable of generating the feedback patterns that exist between multiple human drivers, patterns which are vital to an understanding of multiple-role driving questions.

One solution is multiple seat driving simulation (MSDS), in which several human drivers interact in the same virtual environment. Although rare, MSDS has been used before to tease apart questions involving multiple driver collaborative feedback. For example, in a Liberty Mutual Medal winning study, researchers used linked simulation environments to introduce pairs of human drivers to inevitable mutual collisions. The results shed light on Linked Avoidance Response, in which each driver's avoidance actions cancel out that of the other, leading to a collision. MSDSs allowed this phenomenon to be observed for the first time in a laboratory setting (Hancock & DeRidder, 2003), a feat impossible without a second human mind controlling a second wheel. Researchers were able to better explore issues surrounding the confluence of multiple human drivers by exploiting multiple seat simulation.

Traditional single-seat driving simulation (SSDS) likewise struggles to provide meaningful data in multiple-role

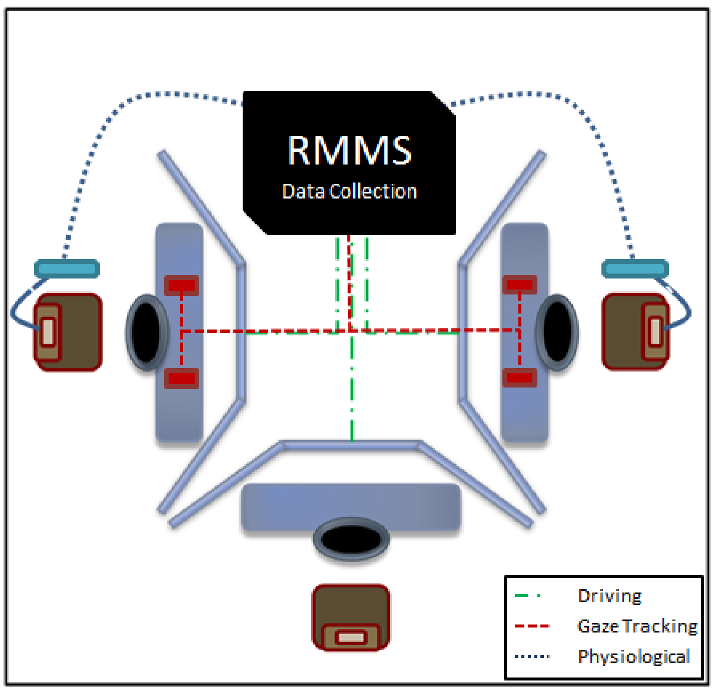

Fig. 2: RMMS Network. Central data collection allows multiple participants to be evaluated simultaneously.

questions such as the ones ITS technologies pose. The root of this problem is obtaining representative data collection. In any simulation of a situation involving two driving roles, the experiment would ideally account for both. In SSDSs two simulation environments, one in each role, must be scripted. Two human participants must be run at separate times, each driving with an AI designed to emulate another human. The possibility that that the program fails to resemble actual driver behavior aside, the amount of work required to generate data that is minimally representative of real world multiple-role driving situation quickly adds up. If the situation to be simulated involves three driving roles, it becomes even more complex, and the associated work ever less manageable. MSDS use simplifies both gathering and analysis of the resultant data. Because two drivers share experiences, potential confounds involving mismatched cues or manipulations are likewise avoided. Instead of analyzing two experiments and then associating them, to sets of entirely comparable measures can be held side-by-side and statistically evaluated. More representative data can therefore be produced and evaluated in a shorter time.

Fig. 3. A Participant in RMMS pod 2

RMMS at UCF: A Networked Driving Simulator

Despite their myriad advantages, MSDS systems are currently a rarity in research. In fact, research simulators do not generally include networking capability. This feature is, however, routinely included in training simulators. Officers of the law, truck drivers, race car drivers, and other professional denizens of the road routinely train risky maneuvers in simulated environments. The simple economic advantages that training students in groups has always afforded, as well as the opportunity for students to collaborate and instructors to demonstrate within an environment has made networked simulation a popular feature.

The following project involves three training simulators. In light of the many advantages of multiple seat driving simulators, we have been endeavoring to enhance these training simulators to provide the advantages of research simulators while retaining their ability to put multiple participants in a shared environment. These units are increasingly functional, and have begun allowing us to scrutinize driver behavior in ways that let participants interact, preserve ecological validity, and retain experimental control.

The Real-time Multiple Seat Simulator (RMSS, pronounced ‘rims’, Fig. 1, 3) operated by The University of Central Florida’s Applied Experimental and Human Factors Psychology program is composed of three fixed platform L3 PatrolSim three channel police training simulators. Each presents a 270 degree virtual driving environment at 1024 x 768 pixels with a refresh rate of 60 Hz. The cab of each PatrolSim is realistic, with controls and indicators taken from an actual GE vehicle. Data collection for the original component simulators was rudimentary, providing only speed and braking data. However, by tapping into the UDP datastream which controls the simulation environment, our team at UCF have been able to record data that includes lane position, time to collision, and a range of break and reaction time measures. Driving data can currently be gathered two human drivers in tandem, and we are working on adding collection for a third. Two of our simulators are connected to Seeing Machines eye trackers, allowing for analysis of visual attention. Two iWorx physiological measurement systems complete the picture, allowing for galvanic skin response, electroencephalogram, heart rate variability, at a range of other useful physiological measures to be collected. All systems are time synchronized, simplifying final data analysis.

It is important to note here that the construction of this network is only recently complete, and not all components are fully functional. The challenges of creating a stable simulation environment are considerable, and building a unified data collection experience presents further difficulties. In particular unifying four software platforms (Fig. 2), namely faceLAB 5 (Fig. 4), an eye tracking suite, GE iSim Research Companion (GIRC), our in-house driving data collection utility, LabScribe, used to collect iWorx physiological data, and ePrime, used for presentation of stimuli and collection of responses, has proved quite difficult. Simple Network Time Protocol (SNTP) clients are part of the solution, as they allow multiple computers running different software to be synchronized within the 60th of a second. The resultant data can then be merged on a spreadsheet quite easily, and this process can be automated through some simple macro work. Another excellent tool has been Virtual Network Computing (VNC) which allows the display of the screen one computer on another over the network. In particular, we are using VNC clients to display the screen of the computer on a tablet mounted next to the participant in order to allow the display of experimental instrumentation, simultaneous presentation of stimuli, and to allow the interface of programs like ePrime to be presented on an in-vehicle screen. At present, the network is stable enough that we have begun using two seats of it to collect data. The most recent information on the state of UCF RMSS and associated research can be found at the MIT^2 laboratory website (2012).

In using RMMS, we've come across a number of collateral advantages. For example, even when not running networked collaborative scenarios, we can still run a single scenario on multiple seats at the same time. This gives the ability for a small team of trained research assistants to run a

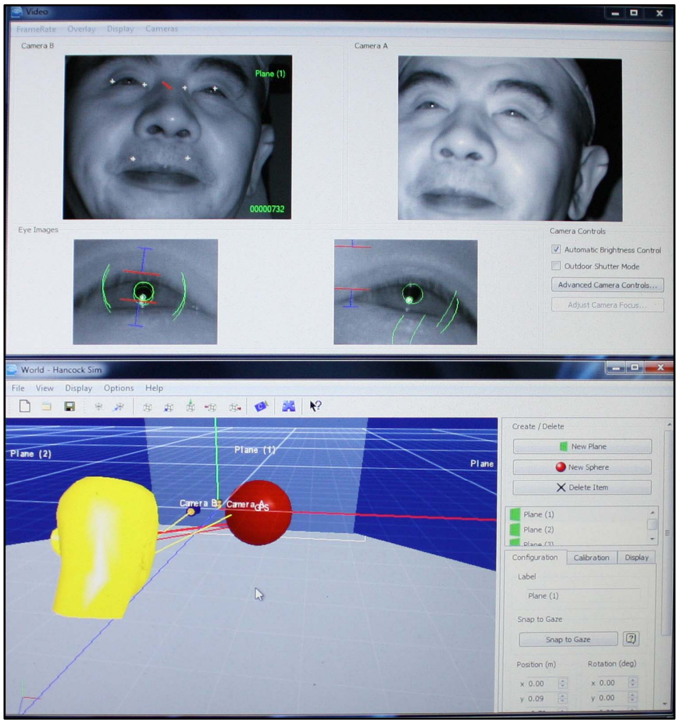

Fig. 4. faceLAB 5, an eye tracking suite used in RMSS.

large number of participants in a short time. Indeed, it appears that with practice a single individual might be able to run three participants at the same time, effectively cutting our time to finish experimentation by more than half. In addition, network simulation provides a ready solution to the inflexible and often unrealistic behavior that artificial intelligence controlled vehicles exhibit. The ability to inject additional human – controlled drivers into scenarios allows for research assistant confederates to take the role of other drivers, and affords complex and realistic driving manipulations. This also allows the mixing of human interaction, over a cell phone or radio link,that is directly related to accompanying physical interaction within driving in the environment, potentially allowing the evaluation of team driving and V@V verbal communication. This "Wizard of Oz" research assistant behind the curtain approach has been used previously in simulator research in non-driving applications (Geutner et al, 2004, Hu,et al, 2007). It was previously suggested by Weinberg and Harsham (2009), but to our knowledge has not yet been used in driving simulator research.

We are still learning to use this tool, even as we continue to improve it. Still, the future is clear. By tying together simulators in order to add ecological validity to our scenarios, collect cleaner data, and analyze it more efficiently, We are already able to better investigate a range of driving situations previously hidden in the wide world beyond our laboratories. We believe just as linked vehicles are the future of roadway transportation, so linked driving simulation through multiple seat driving simulators (MSDSs) is the future of driving research. UCF Psychology's Real-time Multiple Seat Simulator (RMSS) is a modest step in the direction of ubiquitous MSDSs in driving research, but we believe in the fruit will bear in terms of demystifying the interaction of drivers with one another and with systems designed to interact with all drivers. We look forward to sharing our findings and working together toward ITS solutions that address drivers as groups as well as individuals.

REFERENCES

Appel, P. H. (2010). A Tour of the Research and Innovative Technology Administration: Implementing Transportation Solutions to Define a New Era. TR News, (267). Retrieved from http://trid.trb.org/view.aspx?id=919418

Hancock, P., & DeRidder, S. (2003). Behavioural accident avoidance science: understanding response in collision incipient conditions. Ergonomics, 46(12), 1111–1135. doi:10.1080/0014013031000136386

Herrtwich, R. G., & Radusch, I. (2011). Editorial for the Special Issue: Deploying vehicle-2-x communication. Computer Networks, 55(14), 3101–3102. doi:10.1016/j.comnet.2011.06.025

Hu, J., Winterboer, A., Nass, C. I., Moore, J. D., & Illowsky, R. (2007). Context & usability testing: user-modeled information presentation in easy and difficult driving conditions. Proceedings of the SIGCHI conference on Human factors in computing systems, CHI ’07 (pp. 1343–1346). New York, NY, USA: ACM. doi:10.1145/1240624.1240827

Misener, J. A., Biswas, S., & Larson, G. (2011). Development of V-to-X systems in North America: The promise, the pitfalls and the prognosis. Computer Networks, 55(14), 3120–3133. doi:10.1016/j.comnet.2011.04.003

MIT2 Website (2012). http://www.mit.cos.ucf.edu

Petra Geutner, Frank Steffens, Dietrich Manstetten, & Gmbh, R. B. (2002). Design of the VICO spoken dialogue system: Evaluation of user expectations by Wizard-of-Oz experiments: A speech driven in-car assistance system. CiteSeerX. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=?doi=10.1.1.136.2571

RITA, Research and Innovative Technology Administration. (2011) *Intelligent Transportation Systems Joint Program Office.* Safety Pilot Driver Acceptance Clinic Overview. Retrieved March 17, 2012 from http://www.its.dot.gov/research/safety_pilot_overview.htm

Stanica, R., Chaput, E., & Beylot, A.-L. (2011). Simulation of vehicular ad-hoc networks: Challenges, review of tools and recommendations. Computer Networks, 55(14), 3179–3188. doi:10.1016/j.comnet.2011.05.007

Weinberg, G., & Harsham, B. (2009). Developing a low-cost driving simulator for the evaluation of in-vehicle technologies. Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI ’09 (pp. 51–54). New York, NY, USA: ACM. doi:10.1145/1620509.1620519