CrIS | Crash Imminent Safety UTC

Program Progress Performance Report

Project Title: Human Factors for Crash Imminent Safety in Intelligent Vehicles

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CENTER FOR AUTOMOTIVE RESEARCH

Overview:

The primary goal of the Crash Imminent Safety University Transportation Center (CrIS UTC) is **to increase understanding technology design and improve the ways humans interact with intelligent, automated and semi-automated vehicles, and to ultimately use this technology to save lives.**

This lead institution for this center is The Ohio State University (OSU) and consortium members consist of North Carolina A&T University (NCAT), Indiana University-Purdue University Indianapolis (IUOII), the University of Massachusetts Amherst (UMASS Amherst) and the University of Wisconsin (UW).

CrIS UTC is comprised of **seven interconnected research projects** that address four research strategies: driver interaction; pre-crash simulation; human physiology; and policy implications. **Each project has stand-alone research objectives described in detail in each Project section of this PPPR**.

The Center produced its third newsletter at the end of the summer semester and held its annual meeting on September 25, 2015. Researchers (professors and their students) from all partnering institutions presented and discussed their latest research results, along with the challenges and priorities for future direction. Center Leadership also met with the Internal and Advisory Board (IAB) while their students had a concurrent interactive demonstration and discussion section.

On October 9, the CrIS UTC External Advisory Board met and gave valuable feedback which we will use to shape our research direction. They emphasized Weather, Infrastructure, Driver Training, and HMI as very important midterm problems that need to be solved.

The CrIS UTC spring/summer seminar series addressed a broad set of scientific and technical themes in automated and connected vehicle research. Guest speakers included: Lina Fu, Xerox, Research Center, Rochester, New York, Tulga Ersal, University of Michigan, Ann Arbor, Michigan, and Hitay Ozbay, Bilkent University, Ankara Turkey. Approximately 50 students and faculty attended the series.

Project SMOOTH (Smart Mobile Operation: OSU Transportation Hub) debuted on June 2015 in Washington DC as part of the Global Cities Team Challenge. Two smaller automated vehicles at personal scale and four-person scale were developed to be part of an on-demand mobility solution that integrates with the infrastructure of a smarter city. This activity is directly related to the UTC goals of vehicle and pedestrian safety and system reliability and increasing mobility by expanding access to transportation infrastructure.

Collaboration is demonstrated through our institutional team partnerships and also through community and industry involvement at each of our institutions.

All project leads and collaborating institutions participate in a monthly CrIS UTC research leadership conference call to discuss our findings.

Weekly presentations on the projects are being conducted at North Carolina A&T State University to seek and share advice from other graduate students and faculty members.

The Columbus, Ohio team collaborates with state and local public partners, non-profit community partners and industry partners including Battelle, the City of Columbus, CISCO and the Mid-Ohio Regional Planning Commission. At Ohio State, collaborations with DURA and Toyota Information Technologies continue.

Education and Outreach—F. Ozguner

Primary Goal: To transfer the knowledge gained through CrIS research efforts to the next generation of ITS engineers and for use to develop policies related to autonomous vehicle technologies through activities focused on technology transfer. In this past reporting period, CrIS UTC researchers undertook the following activities:

Activity 1-*STEM Summer Program:* We offered the highly successful Women in Engineering (WiE) RISE camp "How to Train Your Robot" for high achieving high school students again last summer. Students participated in a week long workshop developed by graduate students and faculty at CrIS UTC where they learned to program and use a mini robot named 'Sparki'. Sparki's abilities as a robot car mimic the same challenges of designing autonomous vehicles such as convoying, lane changing, line following, and object avoidance. This year, the camp was extended to include more hands-on time for the 39 anticipated attendees.

Activity 2-*Undergraduate Independent Study:* One undergraduate student worked with LIDAR sensors and developed an obstacle detection and navigation algorithm for vehicles moving at low speeds, such as material transport or people transport devices. Another undergraduate worked with an FPGA board to program image processing algorithms for lane detection.

Activity 3-*Senior Capstone Design:* Two groups of students in the Ohio State Electrical and Computer engineering (ECE) capstone design program for spring 2015 designed and implemented a robotic cargo transporter that would follow a human being inside a building while also avoiding collisions with obstacles. One group used passive image-based sensing; involving a visual tag placed on the person to be followed, and the other used an active stereo ultrasonic system to measure distance and angle to the person wearing the transponder.

In fall 2014, one group of 4 students in IUPUI Electrical and Computer engineering (ECE) capstone design course designed and implemented a robotic vehicle speed controller. The robotic controller is to be used to support constant low vehicle speed in testing of pedestrian automatic emergency braking systems.

At NCAT, a team of undergraduate students are working on their senior design project by using the desktop driving simulator. They are gaining fundamental knowledge in research relating to crash imminent safety and driving simulators in general.

In addition, some undergraduate volunteers are working with the driving simulator under supervision. They aid in conducting experiments on the simulator as well as data collection. A great wealth of resources has been provided to the undergraduates in the NCAT ECE department as a result of their participation in this project.

Activity 4-*Advanced Graduate Training:*
ECE 7855: Advanced graduate students were introduced to the complexity of decision-making, the analogies between engineering, economic and societal systems, and the interdisciplinary nature of control engineering in ECE 7855, Large Scale and Cyber-Physical Systems. They also explored the interconnected dynamic system related problems dealing with performance and stability of transportation systems, including the hierarchical layering of information in directing traffic, decomposition issues in analyzing traffic networks, collaborative guidance of semi- autonomous vehicles on roadways and control of car/truck convoys. (The transportation related issues are a new component of this course.)
CE 5760: ***Network Metrics and Control in Transportation Systems (Professor Benn Coifman-3 semester credits for either undergraduate or graduate students).*** This course covers fundamental analysis tools including: time space diagram, queuing theory, traffic flow theory, and further network theory. The course also includes application to intersection control (signal timing).
ISE 5740: ***Human-centered Automation Systems (Professor David Woods -3 semester credits).*** This graduate course studies design strategies for development of automation systems and their human interfaces. The course is offered every other year, will consider autonomy in ground vehicles as a focus area.
Activity 5-*Graduate student exchange program*: For the first time, CrIS UTC collaborating universities held a graduate student exchange program on driving simulator training from June 20 to 27. Allan Anzagira and Saina Ramyar from North Carolina A & T State University and Peng Liu from The Ohio State University attended the program which was hosted by Professor Don Fisher's group at the Arbella Insurance Human Performance Lab (HPL) at the University of Massachusetts Amherst. The week was full of exciting opportunities to learn more about how to construct scenes and scenarios on the RTI driving simulator; how to use an eye tracker to gather information critical to understanding how to make vehicles (and drivers) more

safe, and how to design experiments on the simulator which can answer the particular questions researchers develop.

Facilities and Experiments—K. Redmill

- We have upgraded the operating systems and RTI driving simulation software to the most current version at both the OSU Driving Simulator Lab and the CITR simulation lab, which allows for model and software compatibility and facilitates the interfacing, performance, and operation of the networked simulation activities. UMass Amherst has installed Version 3.0 of the RTI software, added another RTI three screen simulator so that the UMass Amherst and OSU efforts to create distributed driving simulator experiments could proceed in parallel with the experiments which are running on the larger RTI simulator, and purchased and installed SimDriver in order to add a vehicle with some of the capabilities that we expect autonomous vehicles to have in the near future.
- We have also upgraded the furniture in the CITR simulator lab used by UTC researchers.
- As part of the Global Cities Initiative, we have fully automated two small vehicles- a golf cart and a single-person mobility scooter, in order to explore first and last mile transportation issues using small-scale people movers. This activity, partially supported by the UTC as well as an NSF Eager grant, is directly related to the UTC goals of vehicle and pedestrian safety and system reliability, and to increasing mobility by expanding access to transportation infrastructure. The city of Columbus is also a partner in this activity. This activity also requires an expansion of our wide-area communications equipment and capabilities.
- Undergraduate students, through the ECE capstone course, have designed, implemented, and revised the drive-by- wire functionality on these small vehicles.
- We continue to acquire access to naturalistic driving study databases for use by UTC researchers.

This includes the required IRB and human subject protocols training for researchers and students.

- We are automating a passenger sedan for studies on sensing and control issues related to automated parking and automated navigation in parking lots and garages, which are often the source for low-speed vehicle impacts.
- We are evaluating newly acquired Velodyne LIDAR sensors.
- We are studying the implementation of autonomous and semi-autonomous vehicles within the driving simulator software environment.
- There is continued development of the IUPUI/TASI automated braking performance testing environment and CAAIS, the computer assisted alcohol level feedback control device for use in driving simulator research.
- The UTC is working with other stakeholders to support the development of new automated and connected vehicle testing facilities at the Transportation Research Center in East Liberty. OH.

Project 1. Pre-crash Multi-vehicle Experimental Analysis Using a Networked Multiple Driving Simulator Facility
Investigators—Weisenberger (OSU), lead; Chen (IUPUI); Fisher (UMass); Homaifar (NCA&T)**;** Lee (UW); Ü. Özgüner (OSU); Redmill (OSU); Stredney (OSU)

Major Goals - Year 2: Design collaborative multi-vehicle experiments, and use the networked simulation environment to test hypotheses and collect/analyze data for multi-vehicle scenarios.

Accomplishments: In Year 2 of the UTC, Project 1 continues to work toward the networking of driving simulators across the institutions in the CrIS UTC.
Progress: We have made some progress toward this goal, but much remains to be done. One of the biggest challenges in recent months was getting simulators at the partner universities on the internet so that networking could occur. Because the RTI software used by most of the partners was running on Windows XP platforms, partner universities were reluctant to allow these computers to be placed on the

network, given Microsoft's discontinuation of support for this operating system. Further complicating matters was an upgrade in RTI's software. Version 3.0 of SimCreator and SimObserver is designed to run under Windows 7. Networking simulations that ran under the older versions of these programs did not immediately work under Version 3.0.

Over the past few months, most of the partner universities, along with Ohio State, have upgraded both the operating system and the software for their simulators. We have re-established a two-simulator joint scenario, where both vehicles can see each other as well as the traffic operating in the scenario. In the last few weeks, we have re-established the VPN connection with IUPUI and with UMass Amherst, and will proceed with getting joint simulation scenarios operative.

Plans: We hope to have the multi-simulator testbed in place in the next six months and then design and run a pilot experiment during the last six months of the next reporting period.

At the end of March of this year (2015), the University of Massachusetts Amherst (UMass Amherst) upgraded to Windows 7, moved to Version 3.0 of the RTI software, and added a VPN at our site, all of which are required for connecting the RTI simulator here at UMass Amherst with the RTI at Ohio State. Our upgrade was delayed because of the need to coordinate with RTI and our own schedules. UMass Amherst is now actively trying to connect with OSU.

Goals and objectives: There has been no change in overall goals or objectives.

Products: Nothing to report

Collaborations: All of the partner universities in the CrIS UTC are part of this project. Primary work on the networking issues has been done by Thomas Kerwin (Research Scientist), Nishan Noronha and Patrick Veith (undergraduate students) at OSU and Siby Samuel and UMass Amherst. Several additional projects are underway in the OSU Driving Simulation Laboratory that are related to the overall goals of the UTC. These projects include:

1. A collaborative research effort continues with an industry partner to develop a comprehensive approach to develop "suites" of warning indicators for drivers in the vehicle. At present, notifications and warnings are developed by different teams of engineers creating different parts of vehicles, without much consideration as to how these warnings are perceived relative to each other, in terms of urgency or annoyance. The outcome will be guidelines for how to create effective systems of warnings and notifications for the driver. These guidelines will be important for keeping the driver informed as vehicles incorporate an increasing number of autonomous systems. Students participating in the project include Nishan Noronha, Patrick Veith, Tyler Whitlock, Jillian Zhang, Katelyn Silveous, Diana Dumenova, Kevin Smearsoll, Sarah Kasper, and Sean Harrington (all undergraduates).

2. An effort currently underway with Ohio State faculty to assess the question of "road rage" among drivers, specifically the factors that increase aggressive behaviors in driving. Tyler Whitlock (undergraduate) is developing this project as his senior research thesis in psychology.

3. An assessment of how cognitive workload, the detectability and perception of warnings, and driver behavior are affected by the presence of other factors in the vehicle that are not currently classified as distractors by the NHTSA guidelines. In the first study, the impact of the presence and level of background music in the vehicle on situational awareness, driving performance and rated urgency of warnings and notifications is underway. Students participating in this project include Katelyn Silveous, Nishan Noronha, Tyler Whitlock, and Jillian Zhang. A first experiment has been completed as part of Katelyn Silveous's undergraduate research thesis in speech and hearing science. A second undergraduate research thesis is underway in the laboratory, conducted by Sarah Kasper from Speech and Hearing Science. She is extending the project of Katelyn Silveous from last year, in which it was found the loud levels of background audio in the vehicle were correlated with higher driving speeds and decreased urgency ratings of auditory warnings.

Additionally, NCA&T has bi-weekly meetings with Ohio State University, in which we update each other on our recent developments, discuss the challenges in research and receive useful feedback on how to solve the issues and move forward. For this project, we have worked closely together in order to connect our simulator to the network with the other participating universities and the related issues.

Impact: No impact has as yet been demonstrated. Upon completion, the existence of a network of driving simulators will provide a testing resource that does not currently exist elsewhere in the country. This will be a significant output of the center, which will contribute to outcomes by improving our understanding of driver interactions in crash-imminent scenarios, and ultimately to a broader impact in increasing safety for drivers of cars with autonomous vehicle systems.

Changes or Problems: It continues to be challenging to network the simulators across all sites in the UTC. We are making progress and hope to be able to provide some bandwidth and time delay metrics in the next 6 months.

Project 2. Driver Models for Both Human and Autonomous Vehicles with Different Sensing Technologies and Near-crash Activity

Investigators—Ü. Özgüner (OSU), lead; Fisher (UMass); Homaifar (NCA&T)**;** Lee (UW); Woods (OSU)

Major Goals - Year 2: Ohio State has developed the multi-agent models of the driver and the vehicle that can be used to inform the design principles for optimized autonomous vehicles. In Year 2, we are continuing our model-building and estimation efforts, and starting to investigate possible closed-loop impact through future active safety systems that make decisions based on the insight generated by human driver models.

Accomplishments

CrIS UTC researchers are studying different methods of capturing driver behavior in computational and functional models. These models are developed as a means of understanding and quantifying human driving behavior, to be used in Advanced Driver Assistance Systems (ADAS) or partial/full automation applications.

Our focus is on crash-imminent and crash-possible scenarios. As part of the work done at OSU, driver behavior classification approaches for different scenarios were designed specifically considering decisive dangerous features extracted from naturalistic driving data sets. A decisive feature detection module was integrated into a probabilistic driver behavior classifier based on Hidden Markov Models (HMM) to enhance the classification ability of the HMM classifier.

New in this reporting period, the developed classifier was tied into a convoy controller to react to detected/estimated dangerous behavior. This effort forms a major step towards closing the loop from the estimation/prediction side afforded by the human driver models, to the control side represented by more intelligent active safety systems of the future.

In a parallel track, Takagi-Sugeno fuzzy models are used in a data driven technique to model and predict driver's behavior at intersections. In the proposed technique, a Takagi-Sugeno model is trained for each maneuver using a Gath-Geva clustering based algorithm. The proposed models were then evaluated with real time experimental data, and the prediction results are presented in the prepared conference paper listed in the products section.

NCA&T has completed an extensive literature review on driver behavior modeling techniques such as Hidden Markov Models (HMM), Dynamic Bayesian Network (DBN), approximate reasoning, and Model Predictive Control (MPC). Two graduate students are working on modeling the driver behavior using a variety of aforementioned techniques and a tradeoff study will be done on their merits. We are also working on other machine learning techniques which can better model driver intentions.

Currently, NCA&T is investigating to improve the HMM model performance and on analyzing the parameter sensitivity of the HMM to initial conditions. In HMM, the parameters are trained using maximum likelihood (ML) criterion based on expectation maximization algorithm (Baum–Welch

Algorithm). It is guaranteed that a local optimum can be achieved by this algorithm. Improving the algorithm in such a way that it will achieve a global optimum solution or better classification accuracy is the focus of our research. We are also working on modeling driver behavior at an intersection using fuzzy systems, in order to capture the nonlinearity and uncertainty in the behavior of a human driver. We have employed Gath-Geva fuzzy clustering and came up with a model for each one of the driver's actions at the intersection. In the future, we plan to improve the performance of this model by integrating a sense of the distance.

UMass Amherst has worked on the development of Partially Observable Markov Decision Processes (POMDPs) that can be used when to intervene with a warning if a driver is identified as distracted. This research has led to multiple publications.

NCA&T has done the necessary study to use the SHRP2 data for more realistic simulations. One student has already received the necessary IRB training and the other two are in the process.

Products: A number of conference publications were prepared, submitted or appeared as part of the work done in Project 2 in the last six months:

Amsalu, S. B., Homaifar, A., Afghah, F., Ramyar, S., & Kurt, A. (2015, June). Driver behavior modeling near intersections using support vector machines based on statistical feature extraction. In *Intelligent Vehicles Symposium (IV), 2015 IEEE* (pp. 1270-1275). IEEE.

Gorji Sefidmazgi, M., Kordmahalleh, M. M., Homaifar, A., & Karimoddini, A. (2015). Switched Linear System Identification based on Bounded-Switching Clustering. In *the American Control Conference (ACC) 2015*.

Liu, P., & Ozguner, U. (2015, July). Predictive control of a vehicle convoy considering lane change behavior of the preceding vehicle. In *American Control Conference (ACC), 2015* (pp. 4374-4379). IEEE.

Ramyar, S., Sefidmazgi, M., Amsalu, S. B., Anzagira, A., Homaifar, A., Karimoddini, A., Kurt, A. (2015, September) Modeling Driver Behavior at Intersections with Takagi-Sugeno Fuzzy Models. In *Proceedings of 18th IEEE 2015 Intelligent Vehicle Symposium,* Seoul, Korea.

Ramyar, S., Anzagira, A., Homaifar, A., & Kurt, A. (2016). Fuzzy Model for Estimation of Driver's Actions at Intersections. Transportation Research Board 95th Annual Meeting, Washington, DC. (Submitted)

Liu, P., Kurt, A., Redmill, K., Ozguner, U. (2016, January). Classification of Highway Lane Change Behavior to Detect Dangerous Cut-in Maneuvers. Accepted to appear in *Proceedings of TRB 2016 Annual Meeting*.

Liu, P., Kurt, A., Redmill, K., Ozguner, U. (2015, November). Predictive Control of a Vehicle Convoy Considering Lane Change Behavior of the Preceding Vehicle. Accepted to appear in *Proceedings of 9th UTC Conference on Connected and Autonomous Vehicles.*

Strayer, D.L. and Fisher, D. L. (in press). SPIDER: A Model of Driver Distraction and Situation Awareness. *Human Factors*.

Fisher, D.L. and Strayer, D. L. (2014). Modelling situation awareness and crash risk. The *Annals of Advances in Automotive Medicine, 58,* 33-39.

Fisher, D.L. (in press). Cognitive Distraction in the Wild: Next Steps – Addressing a not so Humdrum Conundrum (commentary). *Human Factors*.

Kurt, A., Özbilgin, G., Redmill, K., Sherony, R. et al., (2015) Test Scenarios, Equipment and Testing Process for LDW LDP Performance Evaluation," SAE Technical Paper 2015-01-1404.

Khayyer, P, Ozguner, U (2015, in press) Adaptive Estimation of Energy Factors in an Intelligent Convoy of Vehicles, IEEE Transactin on Intelligent Transportation Systems

HomChauduri, Baisravan, Pisu, Pierluigi and Ozguner, Umit (2015) Secure Vehicle Localization and Cruise Control for Connected Vehicles, IFAC-PapersOnLine 48-21 (2015) 1102-1197

Ozatay, E, Ozguner,U, Filev, D, Michelini, J (in press) Bayesian Traffic-Light Parameter Tracking Based on Semihidden Markov Models, IEEE Transactin on Intelligent Transportation Systems

Adamey, E., Ozbilgin, G., and Ozguner, U., "Collaborative Vehicle Tracking in Mixed-Traffic Environments: Scaled-Down Tests Using SimVille," SAE Technical Paper 2015-01-0282.

Collaborations: CrIS UTC researchers have initiated a dialogue with the data steward of the Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS) in order to obtain statistically significant driving data. This data is to be used in training driver models using different methods such as Hidden Markov Models, as the available data to the CrIS researchers proved to be contain too few relevant (crash-imminent) scenarios.

Currently, both OSU and NCA&T researchers are working to obtain the required IRB certification to further develop the agreement between TRB/VTTI (on the SHRP2 side) and CrIS.

NCA&T and Ohio State continue to work together to develop a driver model at an intersection using Hidden Markov Model and Support Vector Machine from a driving data collected in Ohio State University. NCA&T has also received the naturalistic driving data that was collected in Columbus, Ohio from Ohio State University. It has helped us a great deal in the implementation and evaluation of our proposed models for driver behavior.

Impact: Nothing to report.

Changes or Problems: CrIS UTC researchers have continued to make progress to obtain data from Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS). This data is to be used in training driver models using different methods such as Hidden Markov Models, as the available data to the CrIS researchers proved to be contain too few relevant (crash-imminent) scenarios.

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Project 3. Cognitive Attention Models for Driver Engagement in Intelligent and Semi-autonomous Vehicles

Investigators—Lee (UW), lead; Fisher (UMass); Homaifar (NCA&T)**;** Woods (OSU)

Major Goals - Year 2: In this project we undertake multiple ***Sub-Projects,*** each concentrating on a different aspect of refining the model of driver-automation interaction and assess performance in response to critical pre-crash safety events.

3.1 The Role of Attention in Intelligent and Semi-Autonomous Vehicles.

In December of 2014, UMass Amherst added SimDriver, an RTI software product, to its suite of simulator software. In addition, they are helping add to the functionality of SimDriver, an RTI software product, that will allow the partners in this UTC with an RTI simulator to provide the driver's vehicle with the autonomous and semi-autonomous capability needed to evaluate the transfer of control from the automated driving suite (ADS) to the human driver and conversely.

1. It was shown that there are disrupting effects of in-vehicle glances on hazard anticipation when compared with drivers who glance continuously at the roadway. In particular, eye movement analyses showed that interrupted drivers often failed to continue scanning for a potential hazard when their forward view reappeared, especially when the potential threat could not easily be localized (Borowsky et al., 2014, 2015). The development of in-vehicle systems that were able to detect latent threats could help reduce the risk of in-vehicle glances on hazard anticipation.
2. It was shown that the minimum time that drivers require in order to anticipate hazards when glancing back and forth between the inside of the vehicle and the forward roadway can be as much as seven

seconds, assuming that the in-vehicle task does not require the driver while glancing up at the forward roadway to continue processing in-vehicle information (Samuel & Fisher, 2015a, b; Samuel et al., 2015).

3. An analysis was undertaken of the duration of successive glances in a sequence of glances inside the vehicle, such multiple glances being typical of many of the in-vehicle tasks planned for semi-autonomous vehicles. Several different types of in-vehicle tasks were used. The sequential analysis drivers showed that the third and later glances were particularly problematic for some tasks whereas all glances in a sequence (typically 6-7 glances to complete an in-vehicle task) were problematic when glancing at a GPS (Yamani et al., accepted). The sequential analysis of in-vehicle glance data can be useful for researchers and practitioners and has implications for the development and evaluation of task and interface design.
4. Given that maps produce especially long glances across all glances in a sequence and given that maps are likely to be part of any semi-autonomous vehicle, it seemed important to determine whether an alternative display of the information in a map might decrease the frequency of especially long glances. Surprisingly, it did not do so (Takahashi et al., 2015). Thus, there is still much to do here.
5. A model – the AC/DC (automatic control/driver control) -- was developed for the emergency transfer of control from the ADS to the driver that can be used to predict the actions (e.g., steer left, brake) of the driver given knowledge of the drivers' level of driving ability, subjective evaluation of his or her driving ability, and trust in automation (Samuel, accepted). (b) Plans. Now that we have SimDriver installed, we have two experiments we plan to conduct that will refine the model of driver-automation interaction and assess performance in response to critical pre-crash safety events. Specifically, we will now assume a much higher level of automation where the driver actually relinquishes full control to the ADS. The question we will address in the first experiment is how long at a minimum before a driver takes over manual control he or she must be alerted that such will occur in order for the driver to remain as safe when taking over manual control as he or she would when in full manual mode. The ideal is often referred to as a bumpless transfer of control. In the second experiment, we will address the question of whether we can predict with the AC/DC model the driver's actions when control must be transferred immediately from the ADS to the driver.

6) An experiment was run to determine what minimum time was needed in order for a driver to remain fully situationally aware when control was transferred from the ADS (automated driving suite) to the driver. Using a driving simulator and eye tracker, it was determined that at least 8 seconds warning was needed (Samuel et al., accepted). This experiment also relates to 3.2 below.

(7) A paper describing a general protocol for assessing vehicle automation was completed. Elements of the protocol described in the paper have been implemented and are being documented for dissemination. This paper describes the need to consider automation interactions in the context of secondary tasks that will likely occupy drivers. An engaging secondary task that precisely logs driver interactions has been developed. The paper also describes elements of the driving scenario, with a focus on latent hazards for automation. Here latent hazards are those situations that the automation might not be able to address. A study exercising this protocol is planned to be completed later this year.

8) A preliminary driver model has been implemented in Matlab and coupled to a driving simulator. This model generates driver response trajectories for imminent collision situations and makes it possible to assess the efficacy of automation concepts in a Monte Carlo fashion. An initial application of this model translates measures of near crash outcomes collected in a driving simulator experiment to measures of expected crash distributions that might be obtained if thousands of participants could be included in a simulator study. A paper describing this model has been submitted to the SAE conference.

9) Finally, an experiment was run to determine whether V2I communications could warn drivers in general of upcoming latent hazards without distracting them at the same time (Anzagira et al., in press).

North Carolina A&T State University has purchased an eye tracker from Gazepoint for driver distraction detection. Three PhD students and two undergraduate students are working on projects 1, 2, and 3

3.2 The Smooth Transfer of Control Between the Responsible Human Driver and the Artificial Driving Suite (ADS)

This sub-project asks several questions about bumpless transfer of control in shared control between human driver and Artificial Driving Suite (ADS). How does the responsible human transfer authority to the ADS for it to handle the vehicle within a defined limit of authority or a safe operational envelope (SOE)? Then when the situation and context change — the ADS is reaching the end of the delegated operational envelope — how does the human take back authority resuming direct control or re-task the ADS within a new limit of authority?

The goal is to investigate the form of shared control in terms of how the human driver delegates authority to the ADS to function autonomously within a specified safe operational envelope (SOE). The ADS then needs to monitor when it is beginning to reach the limit of the SOE as the driving situation and context changes, and in the event of onboard failures. Other work in Project 3 looks at how fast people can re-engage when signaled in different way (see 3.1 above). In this new model for shared control the human driver and ADS interact through delegating, monitoring and changing a shared SOE.

To study shared control in terms of monitoring and modifying a SOE requires simulating driving transition situations that require transfers of control between the responsible human driver and ADS have been captured. The transition scenarios (a) begin with an initial delegation of authority from the human driver to the ADS that specifies a specific SOE for that driving context; then (b) there is a change in the traffic situation or an anomaly that brings the ADS closer to the limits of its delegated authority; finally (c) the human driver and the ADS coordinate a re-authorization of SOE to adjust to the altered conditions.

Results to date: Three scenarios of this form have been designed and implemented using the OSU driving simulator. A great deal of work has been required to overcome the limitations of the simulator at representing autonomous vehicle activity. The scenarios represent (1) a change in traffic situation that gradually pushed the ADS near its limit of authorization, (2) an anomaly where the ADS plan does not match the actual driving environment, and (3) an anomaly where a failure within the ADS reduces its safe operational envelope (SOE) and triggers the need for the human driver to become aware of the new more limited SOE.

Claims about autonomous operation confound delegation of authority with ADS capability for self-driving in limited conditions. This study explicitly studies the dynamics of delegation of authority and especially re-authorization as new events and traffic change occur. This is a new concept for shared control based. The new form of human-autonomy interaction is based on responsible human and autonomous system interacting around changing an envelope of safe operation and based on communications in terms of delegation of authority from responsible human to autonomous capabilities.

The new concept has led to new project funded by NSF on Bumpless Re-engagement for Shared Control in Layered Networks jointly with MIT. Professor Woods gave talks on the new model at the annual Cognitive Science Society meeting and at NASA Human Sciences Division.

Student Involvement: An undergraduate research assistant has been hired to help run pilot tests with the above scenarios.

3.3 Near Real-time Computation and Utilization of Maximum Safe Operating Envelopes in Coordinated Synthetic Driving

This sub-project addresses how to assess the risk of autonomy. The approach is to develop a risk analysis method for the potential for loss of control depending on the engineering pedigree of the autonomous capability/vehicle and the consequences of loss of control. The goal is to enable near real time calculation and utilization of a maximum safe operational envelope (nrt-max-SOE) based on a combination of the risk analysis and real time data about environmental conditions and human/vehicular activity nearby. The proposed approach to computation and assessment supports shifts to new envelopes as conditions and capabilities indicate the current envelope risks saturation or when conditions present new opportunities. The approach has three main components: maximum safe operating envelope, risk analysis of autonomy, near real time computation.

Maximum safe operating envelope:

- keep activities inside the dynamic envelope as information about changing conditions comes in (open up or restrict activities as events occur and conditions change);
- make bumpless shifts of control/authority across operating envelopes as conditions change (re-engage other roles to pick the desired or appropriate operating envelope and forms of control);
- recognize when operations get near to or risks going outside the envelope and trigger re-assessments and model revision;
- provide graceful extensibility as risk of saturation increases near envelope boundaries.

New form of risk analysis: Some readjustments to traditional risk assessment allow it to consider and be explicit about potential for brittle automation and the potential for loss of control (robustness and resilience). As a result, the risk analysis becomes ready to be actionable in real time.

Near real time: The connectivity revolution is all around us bringing a variety of data to bear at a point of action or point of inquiry. As we shop and search, a variety of factors are considered in real time to target results to that activity (micro ads, search results, point of sale). We can do the same for other activities to specify the “maximum safe operating envelope” for that activity given the risk analysis conditioned by current data and the contextual information available.

As the envelope shrinks or expands with current information, the basis for supervision, re-authorization decisions, and transfer of control changes. Mechanisms for smooth transfer of control are needed to manage these shifts in envelope. Current work examines how to assess the brittleness of any autonomous capability across situations and how to use this information to establish, adjust, and manage the SOE.

Results to date: The basic form of the new method for assessing the risks associated with autonomy has been developed. The basic form for making the risk assessment actionable as a new form of automated safety management has been developed. The innovation is responsive to the widely recognized need for new forms of V&V for autonomous vehicles by NASA and by the National Research Council reports. Future work will provide a notional case study to illustrate the new concept.

Products

***Refereed Journal Publications*:**

Yamani, Y., Horrey, W.J., Liang, Y. and Fisher, D.L. (accepted). Sequential in-vehicle glance distributions: an alternative approach for analyzing glance data. *Human Factors*.

Borowsky, A., Horrey, W.J., Lian, Y., Garabet, A., Simmons, L. and Fisher, D.L. (accepted). The effects of momentary visual disruption on hazard anticipation and awareness in driving. *Traffic Injury Prevention*.

Samuel, S., & Fisher, D.L. (2015b, Accepted) – Evaluation of the Minimum Forward Roadway Glance Duration - *Transportation Research Record, 2015.*

Refereed Conference Proceedings

Anzagira, A., Ramyar, S., Yan, X., Agana, N., Homaifar, A., Fisher, D.L.(2016) Effect of Visual and Auditory Warnings on Latent Hazard Anticipation while Engaged in a Mock Cellphone Task. (Accepted) Transportation Research Board 95th Annual Meeting.

Borowsky, A., Horrey, W., Liang, Y., Simmons, S., Garabet, A. and Fisher, D. L. (October 2014). The role of working memory in driving related hazard anticipation. *Proceedings of the Human Factors and Ergonomics 2014 International Annual Meeting*, Chicago.

Takahashi, M., Yamani, Y., Dündar, C., and Fisher, D. L. (January 2015). Evaluating effectiveness of partitioning complex visual displays on glancing behavior inside of vehicle. *Proceedings of the Transportation Research Board 94th Annual Meeting 2015*, Washington, D.C.

Samuel, S., & Fisher, D. L. (2015a). Evaluation of the Minimum Forward Roadway Glance Duration Critical to Latent Hazard Detection. *Proceedings of the Transportation Research Board 94th Annual Meeting 2015* (No.15-1707), Washington, D.C.

Fisher, D.L. (2015, in press). A Predictive Model of Driver Response in a Level 2/3 Autonomous Environment. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.*

Samuel, S., Romoser, R.E., Knodler, M., and Fisher, D.L. (2015, in press). Evaluating spillover effects on forward roadway glance durations. *Presented at the meetings of the Road Safety and Simulation Conference*, Orlando, FL.

Anzagira, A., Ramyar, S., Yan, X., Agana, N., Homaifar, A., and Fisher, D.L. (2015, in press). Effect of Visual and Auditory Warnings on Latent Hazard Anticipation while Engaged in a Mock Cellphone Task. Proceedings of the Road Safety and Simulation Conference, Orlando, FL.

Samuel, S., Horrey, W. and Fisher, D.L. (2015, in press). A predictive model of driver response in a level 2/3 autonomous environment. *Proceedings of the Human Factors and Ergonomics Society 2015 International Annual Meeting*. Los Angeles: Human Factors and Ergonomics Society.

Samuel, S. and Fisher, D. L. (in press). Minimum time to Situation Awareness in Scenarios Involving Transfer of Control from the Automation. *Accepted for presentation at the 95th Annual Meeting of Transportation Research Board*. Washington, D.C., January.

Gibson, M. C., Lee, J. D., Venkatraman, V., & Price, M. (in press). Situation awareness, scenarios, and secondary tasks: Measuring driver performance and safety margins with highly automated vehicles. *Society of Automotive Engineers*.

Venkatraman, V., Lee, J. D., Schwarz, C. W., & Gunarathne, P. (n.d.). Benefits estimation of collision warning systems: Development of crash risk scales using what-if modeling techniques. *Society of Automotive Engineers*.

Collaborations: NCA&T has been in touch with the University of Massachusetts and the University of Wisconsin who are also working on this project. Experiments on investigation of latent hazard anticipation using the driving simulator are being designed in collaboration with the Human Performance Laboratory of UMASS. In addition, the experiments on driver-vehicle exchange will be performed in collaboration with the University of Massachusetts and the University of Wisconsin. We also had a week-long visit to the University of Massachusetts over the summer, where we had the opportunity to gain experience on eye tracking as well as running experiments on the simulator.

Impact: A team of undergraduate students (team DOT) are working on their senior design project by using desktop driving simulator. They are gaining fundamental knowledge in research relating to crash imminent safety and driving simulators in general.
In addition, some undergraduate volunteers are working with the driving simulator under supervision. They aid in conducting experiments on the simulator as well as data collection. A great wealth of resources has been provided to the undergraduates in the ECE department as a result of our participation in this project.

Challenges or Problems: The main issue being faced in these projects is the lack of experimental data. NCA&T has been working to develop various scenarios, collect data from experiments and more importantly integrate equipment such as eye tracker in order to be able to develop experiments on driver distraction. Currently, we are almost done with the eye tracker integration. However, it would beneficial if we could have greater access to the data that other universities have obtained by conducting various experiments, to have a benchmark for comparison and evaluation of our experiments.

Project 4. Bioinjury Implications of Pre-crash Safety Modeling and Intervention
Investigators—Bolte (OSU), lead; Weisenberger (OSU)

Major Goals - Year 2: Use Bio-Injury data from given crash scenarios to suggest evasive action / driver position best suited to reduce injury.

Accomplishments

Progress (Phase I): This period of performance picks up following the analysis of the NASS-DCS database for the pre-defined scenarios. The major findings were re-analyzed to confirm the initial findings, which are listed below (a new student came on to the project so the re-analysis was done to confirm the ability of the new student): Major Injury Findings: (1) Lead vehicle stopped (Scenario 1): spine & extremities; (2) Vehicle turning at a non-signalized junction (Scenario 2): thorax, (3) Vehicle changes lanes (Scenario 3): head and face.

It was extremely interesting to find that each scenario resulted in a different body region being at the highest risk for serious injury. It is important to note that even though all have differing regions of concern, none of the scenarios had larger than a 2% risk of serious injury.

Progress (Phase II): The main focus during this period of performance was to use a 2nd database, CIREN – (Crash Injury Research & Engineering Network), which focuses on the details of injuries of very specific crashes. While CIREN is not statistically significant, it follows the occupants from the crash to the hospital and includes accident expert's opinions on what each mechanism of injury was (i.e. steering wheel, intruding door, air bag etc.).

1. We currently have access to the public database and are looking at the 3 defined scenarios to see if the injuries in CIREN match the findings from NASS-CDS.
2. It is important to note that for a case to be considered for CIREN an occupant in the vehicle must have sustained at least a serious injury according to the Abbreviated Injury Scale (AIS).

The first step was to scan the CIREN database and pull cases that match the scenarios stated in Phase I. A thorough CIREN search revealed the following number of cases for each scenario: a. Lead Vehicle Stopped –59 cases; b.Vehicle turning – 157 cases; c.Vehicle changes lane – 10 Cases. Lead Vehicle Stopped and Vehicle Turning scenarios have been investigated for patterns of injury mechanisms. The third scenario (Vehicle changes lane) will be investigated once we gather more cases.

To date 59 case studies involving Lead Vehicle Stopped have been analyzed. As stated earlier, according to the statistical analysis of NASS-CDS for these crashes, the most common serious injuries were to the spine and lower extremities.

The CIREN database revealed that the most common serious injuries (AIS 3+) occurred to the thorax, followed by the abdomen, and lower extremities. Of the AIS 3+ injuries to the three regions above, thorax injuries accounted for 36% of the injuries. Close to 40% of the thorax injuries are AIS 4-5. Of the AIS 3+ injuries to the three regions above, abdominal injuries accounted for 13% of the injuries. Over 20% of these injuries are AIS 4-5. Of the AIS 3+ injuries to the three regions above, lower extremity injuries accounted for 51% of the injuries. Most of these injuries were AIS 3. Truck under ride impacts and secondary impacts caused most of these severe injuries to the thorax, abdomen, and lower extremities, which could account for the difference in findings between the NASS-CDS and CIREN searches. The interior vehicle component that caused the most thoracic injuries was the steering wheel (sometimes through the airbag), suggesting that secondary impacts are causing these injuries.

To date 157 cases studies involving a vehicle turning in front of a 2nd vehicle have been analyzed. As stated earlier, according to the statistical analysis of NASS-CDS for these crashes, the most common serious injuries were stated to be to the thoracic region. The CIREN database revealed that the most common serious injuries occurred to the thorax, followed by the head, and abdominal regions. Of the AIS 3+ injuries to the three regions above, serious thoracic injuries account for 47% of the injuries. Of the AIS 3+ injuries to the three regions above, serious head injuries account for nearly 35% of the injuries. Of the AIS 3+ injuries to the three regions above, serious abdominal injuries account for 17% of injuries.

The leading mechanism of injury for these regions was contact with the intruding door structure, followed by b-pillar contact, and contacting a vehicle component through airbags. It will be interesting to further look at cases with varying airbags and other safety features to see if the injury patterns are different. Most of the severe injuries are happening in secondary impacts. For autonomous vehicle programming, we suggest looking into ways to prevent secondary impacts and reduce overcorrection by the driver following initial impacts.

Training or professional development: We have introduced three students (Tim Gocha, Tanisha Kashikar & Lauren Eichaker) to database mining and statistical analysis. This project has allowed us to expand our research center into the realm of data mining. This is proving to be useful on other ongoing projects in the center as well.

Dissemination of Results: The NASS-CDS results have been submitted to the *Annals of Biomedical Engineering.*

Plans for next period: CIREN findings will be analyzed further, defined further, and reported. CIREN findings will be submitted for publication.

***Products*:** Publications – Phase I findings from the NASS-CDS have been written and submitted to the *Annals of Biomedical Engineering*. Phase 2 findings from CIREN are in the process of being written and will be submitted *to IEEE – Transactions on Intelligent Vehicles* (a new section of IEEE that will begin publishing in 2016).

Data: The research will result in crash and injury databases that will be useful to better understand injuries which occur during the 3 defined crash scenarios.

Collaborations (Partners): We have been collaborating with the National Highway Traffic Safety Administration for access to the full CIREN database, which includes radiology images and reports. We also have been discussing correct use of the database and also various injury coding programs that could be used to better define cost to society.

***Impact*:** Discipline: (1) The techniques being developed for mining both databases will help further the role of epidemiology in analyzing autonomous vehicle crash scenarios. (2) These techniques will be published and could also be taught to future researchers in the Injury Biomechanics course (Anat 7892)

Society: Having a better knowledge of injuries that occur in common crash scenarios will lead to safer vehicles and thus reduce fatalities and injuries in future crashes.

Changes/Problems: Nothing to report.

Project 5. Pre-Crash Interactions between Pedestrians and Cyclists and Intelligent Vehicles
Investigators—Chen (IUPUI), lead; Fisher (UMass); Ü. Özgüner (OSU)

Major Goals - Year 2: Validate and refine models using driver simulation tests.

Accomplishments: Progress toward stated objectives and goals: The primary goal for Year 2, Project 5 was to develop simulation models for vehicle to pedestrian/cyclist pre-crash interval.
Major activities, including milestones and dates: TASI at IUPUI has been working on four parallel activities since the start of the program. A summary of these activities are given below:

Activity 1. Create a driving simulation model of a pedestrian forward collision imminent braking (CIB).
Activity 2. Integrate the active safety sensing information in V2V study. Our idea is to link V2V and CIB capabilities together and let a pedestrian CIB system tell other vehicles the presence of pedestrians. If a vehicle can exchange the pedestrian sensing information in real-time, the vehicle can get potential pedestrian crash information before itself can sense the potential crash ,and hence, have more lead time to respond to a potential crash and to improve safety. Three students are working on this problem. The pedestrian CIB model will be used for vehicles to detect pedestrians and broadcast to other vehicles in V2V-CIB simulation.
Activity 3. Transfer the technology of the Computer-assisted Alcohol Infusion System (CAIS). The CAIS apparatus combines a physiologically based pharmacokinetic (PBPK) model of alcohol distribution and

elimination with computer control of infusion pump rate to enable precise control of breath alcohol concentration over time. The precise alcohol level control and driving simulation provide the ideal environment for various types of drunk driving study. The device has been designed and successfully tested. TASI is actively pursuing the collaborative research in drunk driving using CAIS and driving simulators, and technology transfer opportunities of CAIS with our UTC program partners.

Activity 4. Using a dataset developed from the Indiana State Police and linking it with Census information from the American Community Survey to find the incidence related to race, income and poverty status of pedestrians and drivers involved in crashes and the scope for CIB technologies to mitigate them.

Major findings or results:

Activity 1. A PreScan model of a Pedestrian CIB system has been developed. The model uses the PreScan vehicle simulator provided by TASS International. The model describes the CIB performance based on the vehicle speed, pedestrian speeds, pedestrian sizes, the pedestrian motion direction relative to the vehicle motions, and lighting conditions. The goal of Activity 1 has been reached. A better approach is being studied. A Pedestrian CIB model was developed based on the hundreds of pedestrian CIB system tests.

Activity 2. 96 scenarios that V2V-CIB can benefit pedestrians are identified using the exhaustive search method. It was found that current SAE DSRC protocol cannot support V2V-CIB operation so an augmented protocol was proposed. A V2V-CIB simulation for improving pedestrian safety has been developed in the Pre-Scan environment. An architecture for information processing in V2V-CIB system was developed. A simulation tool is developed on top of PreScan is developed to support the algorithm development for V2V-CIB. This tool can greatly speed up the future simulation study of the V2V-CIB system.

Activity 3 A report of the pilot study performed in the IUPUI TASI simulator using CAIS was prepared. The report has been turned into a manuscript for submission to the Research society for Alcoholism.

Activity 4. Preparing a conference "Smart Privacy for Intelligent Systems" to bring together representatives from industry, urban planning and administration, regulatory agencies and academia to identify workable regimes that strike an appropriate balance between data privacy and data usability in systems such as intelligent transportation and smart lighting.

During the first year, UMass reviewed different treatments that have been used to prevent right hook crashes with bicyclists.

Plans for next reporting period:

Activity 1. IUPUI will continue work on the second phase to transfer the pedestrian CIB model generated from PreScan environment to the Realtime Technology driving simulator.

Activity 2. Using the V2V-CIB simulation tool to develop new algorithms for data processing required for V2V-CIB operations, Expand the PreScan model to include large number of Vehicles and pedestrians in the simulation. Develop sensor fusion methods to process the V2V-PCS information efficiently.

Activity 3. Dr. O'Connor will continue to find collaboration partners to disseminate the Alcohol control device in the alcohol related transportation study.

Activity 4. David Good and graduate student Brandon Taylor are nearing completion of linking ACS with the police crash reports. In October 2015 IU School of Public and Environmental Affairs will be hosting a 2 day workshop on "Smart Privacy for Intelligent Systems." This workshop will bring together representatives from industry, urban planning and administration, regulatory agencies and academia to identify workable regimes that strike an appropriate balance between data privacy and data usability in systems such as intelligent transportation and smart lighting. Organizers include Beth Cate and David Good (IU Bloomington).

Goals and objectives: There has been no change in overall goals or objectives.

<u>Products</u>: **Publications, conference, papers, and presentations**

1. Bo Tang, Stanley Chien, and Yaobin Chen, "Obtain a Simulation Model of a Pedestrian Collision Imminent Braking System Based on the Vehicle Testing Data," *17th International IEEE Conference on Intelligent Transportation Systems* in Qingdao China on Oct 9, 2014.
2. Mingxin Liu, Stanley Chien, and Yaobin Chen, "Improve Road Safety Using Combined V2V and Pre-Collision Systems," accepted and to be presented on 2015 ESV conference organized by NHTSA in June 10, 2015.
3. Bo Tang, invited presentation "Use PreScan to Simulate the Integration of V2V and PCS," presented on the PreScan Users Group Meeting on April 20, 2015.
4. Alberto Lopez, Stanley Chien, Lingxi Li, Qiang Yi, Yaobin Chen, Rini Sheroni, Analysis of the Braking Behavior in Pedestrian Automatic Emergency Braking. IEEE 18th International Conference on Intelligent Transportation Systems, Las Palmas de Gran Canaria. Spain; September, 2015.
5. Representing the UTC, Dr. O'Connor has begun a dialog with the President of RealTime Technologies, the manufacturer of the driving simulators employed in the UTC grant.

***Collaborations*:** **In-kind Support** TASS International is providing the PreScan vehicle simulation software to IUPUI for the development of the simulation model and pedestrian CIB and V2V simulation. Facilities Faurecia Emission Control Technologies, USA, LLC is providing vehicle test track to IUPUI for pedestrian/bicyclist CIB data collection.
Facilities: Faurecia Emission Control Technologies, USA, LLC is providing vehicle test track to IUPUI for pedestrian/bicyclist CIB data collection.
Partner's Contribution: Indiana University provided a one year $72K grant for bicyclist naturalistic riding study. The investigators are Stanley Chien, David Good, Jinagyu Zheng, Yaobin Chen, and Lauren Christopher. The result will provide a better understanding of the bicyclists' behavior that is important for simulation models.
Impact: ***On the development of the discipline(s):*** The integrated V2V and CIB sensing enables the transmission of the detected pedestrians and cyclists information to other vehicles that potentially make the other vehicle get information early enough to avoid the pedestrian crashes. The cost for this improved safety for vehicles is low. The video database developed in this project opens a new area of extracting intrinsic and statistical information through transportation data mining.
On the base of knowledge, theory, or methods: The pedestrian CIB modeling activity provides a pedestrian collision imminent braking model for real vehicles. This simulation model provides a realistic reference for the development and improvement of new pedestrian CIB systems. (1) Our new pedestrian detection methods based on motion in the real driving video data not only identify the human walking characteristics, but also contrast to the motion of other scenes. In details, HOG based leg chain detection and Corner based non-smooth motion methods are proposed and examined in order to increasing the detecting accuracy. (2) TTC computation using video data also utilize motion information in the video to avoid vehicle recognition in the video such that a fast and accurate function to avoid vehicle collision can be achieved. (3) We developed the first method to investigate light distribution in night from collected the naturalistic driving video in a city.
On the development of transportation workforce development: Five IUPUI Masters students in the Department of Electrical and Computer Engineering have been working on this project as part of their graduate degree requirements. One PhD student played major role in the algorithm development. Two master students have been involved in the driving video database development and server side programming. Fifteen master students participated in a term project to evaluate the performance and accuracy of our pedestrian detection. Three graduate students and two undergraduate students have selected driving video processing as their independent study course. Five undergraduate students have also participated in the term projects to numerically evaluate the algorithm and method based on sampling videos. One graduate student at IU-Bloomington has been involved as well.
On technology transfer: IUPUI is actively pursuing the transfer and dissemination of the CAIS technology to a Driving simulator company and driving simulation community. The driving video database allows uploading video from external users, which serves as a platform of data collection and analysis.
Changes or problems: Nothing to report.

Project 6. Safety Policy Implications and Information Dissemination

Investigators—Schuelke-Leech (OSU), lead; Ü. Özgüner (OSU), Weisenberger (OSU); Woods (OSU)

Major Goals - Year 2: Develop and modify pre-crash scenarios and experiment plans to better align with hypotheses and outcome assessments that inform policy recommendations.

Accomplishments: Several important activities were undertaken in support of the grant goals and objectives.

1. In the past year, we have further developed our understanding of text data analytics and using corpus linguistics. We have also gathered additional data, which will allow us to further our analysis of the technical and policy issues.
2. Analysis of the data from the U.S. Congress from 1981-2014 showed that sustainability is an important topic of conversation for policy makers. However, there is little discussion of either autonomous vehicles or vehicle safety. These results forced us to look for the policy and regulatory discussions elsewhere, primarily in the U.S. Courts and the U.S. Public Administration. This required gathering new data. This delayed writing and submissions until the data could be obtained. This data has now been gathered and analysis should begin soon. One of the papers that we are working on is what is the driver of the adoption and acceptance of autonomous vehicles (e.g., reducing congestion, safety, fuel efficiency, or commercial potential)? Another paper will look at vehicle safety and whether the primary discussions are focused on technology or human factors. What we have found so far is that there is a disconnection between how entrepreneurs and technical people view human factors as the primary avenue to failure, whereas Congress and the U.S. Courts are more focused on technological failure.

What was learned?: We were forced to re-evaluate the policy conversations when our research showed that autonomous vehicles are a small topic of conversation in Congress and that federal policymakers are not connecting autonomous vehicles to car safety in a meaningful way. We looked at where the conversations around these technologies are occurring, which is much more in the Public Administration. So, we gathered data on the public administration, the U.S. Courts, and from entrepreneurs/engineers, which will allow us to understand both the technical, legal, and policy conversations. Autonomous vehicles are a disruptive technology to the regulatory and legal frameworks that we have for vehicle operations. However, it appears at this point that regulatory and legal changes will be reactive, rather than proactive, engaging with the disruptive technology development early enough to smooth or guide the adoption of the technology. These findings will guide our engagement with policymakers, as we try to ensure that the policy and socio-technical issues that arise from the development and deployment of autonomous vehicles and smart technologies are acknowledged and understood.

Opportunities for Training and Professional Development: Several forums will be held this year at Ohio State University, bringing together different stakeholders to discuss the different technical and policy components of intelligent transportation. Our first forum will be held November 6th, 2015. This forum is co-sponsored by the Moritz College of Law, the College of Engineering, and the John Glenn College of Public Affairs. The forum will focus on aerial transportation systems, but there is an overlap with stakeholders interested in intelligent ground transportation. In the spring, a forum on autonomous vehicles and moral algorithms is scheduled for April, 2016. The purpose of both of these forums is to build bridges between policymakers, engineers, manufacturers, suppliers, and the public.

Dissemination of Results: I gave several presentations on my research this year, including: a presentation at the Humphrey School of Public Affairs, University of Minnesota, February 2, 2015; a lecture on Sustainable Transportation and Public Policy at Ohio State University on April 22nd, 2015; a presentation at the University of Georgia on September 17th; and a presentation at the Atlanta Science and Technology Policy Conference on September 19th. I am planning to give more presentations in the next year, including one of November 11th in Miami. We had difficulty getting our initial results published because of the lack of findings using the Congressional data. With the new data, we are expecting to get two papers submitted this fall. There are several other research papers that will be submitted in the next two months. A presentation was given at the University of Minnesota presenting the findings about autonomous vehicles and safety. In addition, the results are being presented at four conferences this spring and summer. There is a lecture on April 22, 2015 on sustainable mobility incorporating these results.

Next reporting period: In the next reporting period, we are planning to have two papers published. We are also planning on hosting two forums.

Goals and objectives: There has been no change in overall goals or objectives.

Products: Nothing to report

Collaborations: Three visiting scholars worked on the project this year, finishing in February 2015: Dr. Betsy Barry, Dr. Clayton Darwin, and Suzanne Smith, JD. These collaborations continue.

Impact: This research supports work to engage policymakers and practitioners in a meaningful way. Empirical research is absolutely critical for data-driven policy.
Impact on Development of Principal Discipline: This research is both methodological and substantively innovative to this field.

Impact on society beyond science and technology: I have started to engage with people beyond the academic world to discuss the impacts of autonomous vehicles and car safety. I presented to a local community group in Ohio. I am looking to find other opportunities to do this kind of outreach.

Changes or Problem: Nothing to report.

Project 7. Technology and Enhancements to Improve Pre-Crash Safety

Investigators— Ü. Özgüner (OSU), lead; Chen (IUPUI); Coifman (OSU) Homaifar (NCA&T); Ekici (OSU); F. Özgüner (OSU); Redmill (OSU); Zheng (IUPUI)

Major Goals – Year 2: In this project we undertake multiple ***Sub-Projects,*** each concentrating on a different new technology that may have an effect in improving pre-crash safety.

7.1 Secure Data Transfer Methods to Support Crash-Imminent Safety Situations

Accomplishments: The major goal of our effort is to investigate secure data transfer methods to support Crash-Imminent Safety systems. We introduce an innovative confidential V2V and V2I sensitive data transfer protocol that devises a cryptosystem that is different from the symmetric and hybrid counterparts adopted by IEEE 1609. Although the Elliptic Curve Integrated Encryption Scheme (ECIES) has been chosen to be the typical ciphering scheme in the IEEE 1609.2 standard because of its short keys and fast computations, it mainly depends on a preliminary step of obtaining the public key of the other party. Rather than such plain exchange of the input public keys in ECIES, we use the involved vehicles' identities in an obfuscated manner in dynamically generating veiled keys for encoding such delicate data. To examine the suitability of the construction, in-depth analysis in terms of On Board Unit (OBU)'s storage and computational time has been conducted; the results show that the construction is practical and can accommodate large identities.

Products: ***Publications:***

Sarah Al-Shareeda and Fusun Ozguner, "Secure Pairwise Key Establishment in Vehicular Networks", The 3rd International Conference on Connected Vehicles & Expo (ICCVE 2014) Nov 2014, Vienna, Austria

Sarah Al-Shareeda and Fusun Ozguner, "Confidentializing Sensitive Data Transfers in Vehicular Adhoc Networks", submitted to IEEE Transactions on Vehicular Technology.

Collaboration: Nothing to report.

Impact: Nothing to report.

Changes or Problems: Nothing to report.

7.2 Cognitive Radio Based Communication

Major goals: The major goal of our effort is to evaluate the performance of the vehicular cognitive radio networks in the presence of other heterogeneous secondary networks, the joint operation across DSRC and TVWS bands, and efficient channel handoff schemes.

Accomplishments

1) During this reporting period, we continued our simulation study to assess the gains attainable through various approaches to solve challenges associated with the deployment of cognitive radio networks to vehicular environments.
2) The specific objective of our study was to perform a comparative analysis of various dynamic channel selection algorithms to determine their efficacy in terms of vehicular cognitive radio performance and the protection provided to licensed spectrum holders.
3) Our simulation studies have revealed the following:
    a. Longer sensing durations significantly reduce the probability of collision with primary users and are therefore preferable.
    b. Handoff issues across different channel types display similar characteristics as in the case of channel handoff in DSRC band when coordinated centrally. The additional overhead to handoff from a DSRC channel to a TVWS channel is minimal.

Dissemination: At this point, a conference paper is being prepared that outline our findings pertaining to this and the pervious reporting periods.

Next reporting period: Improved simulator developed to assess the performance of 802.11p operation and handoff routines.

Products:
Improved simulator developed to assess the performance of 802.11p and other protocols under the cognitive radio settings.

Impact: Development of the principle discipline: The effort during this reporting period builds upon our previous findings that revealed that long-held beliefs about the use of 802.11p protocol as a very good, real-time communication alternative were indeed unfounded. Our new studies augment these observations with new findings on the effect of sensing periods on the communication performance of the cognitive vehicular networks and the protection of the primary users from the activities of the cognitive vehicular networks. The tradeoffs suggest that the time spent in sensing the spectrum over longer periods has significant advantages in terms of PU protection and has only limited negative impact on data transmission performance. Moreover, we also observe that PU-aware channel selection scheme has the potential to minimize the impact of the vehicular network operation on the primary users.

Changes/Problems: Nothing to report

7.3 EEG and Lane Change Intent

Changes or Problems: This preliminary investigation has concluded. A larger budget and extended effort would be needed for more meaningful results.

7.4 Analyzing and Mining Big Data of Driving Videos for Crash Avoidance

Accomplishments
One major goal in this period is to detect signature events in the surrounding environment from large video dataset. We have explored new methods for pedestrian detection from video, developed algorithm to detect dangerous vehicle speed and compute TTC from video, classified night illumination using distributed video records, and prepared to learn road types and road margin from video database. The data analysis of video has been presented in international conferences and the annual meeting of this project. The plan in the next reporting period is continuing current effort to produce more solid results.

In pedestrian detection based on walking motion, various methods are developed and examined for locating characteristic chain patterns in the motion profile of driving video. Non-smooth points are tested for pedestrian motion classification. In the vehicle collision avoidance, we have located zero-flow in the motion profile and further TTC computation will be based on object size changes. Large area light distribution in night illumination has been investigated in the naturalistic driving video dataset.

Products

We have constructed an online driving video database with video clips, motion profiles, and attributes of traffic and environments. It has functions of upload and download similar to Youtube. It can also search clips of interest by attributes, and displaying temporal motion trajectories of vehicle and surrounding for data mining and accident analysis.

Collaborations

IUPUI is collaborating with NHTSA and Toyota Collaborative Safety Research Center. IUPUI also participated in the SAE Active Safety Standard Committee and lead the Pedestrian Mannequin Task Force. Continue the collaboration with TASS International. Attended SAE 2014 Active Safety Symposium to learn and discuss the latest active safety development in automotive industry.

Impact: This is the first online video database for large scale driving data. It will impact the big data mining in driving videos for extracting various parameters, understanding factors of accidents, and developing and testing algorithms in vehicle sensing and control. For example, new algorithms for pedestrian detection, road side detection, bicyclist detection, and so on will be beneficial from these big data resources.

In education aspect, one PhD student, two master students, and two undergraduate students are working in this project. More students in graduate and undergraduate multimedia classes are involved in data testing.

Changes or Problems: None

7.5 Safety Implications of Traffic Dynamics in Congested Freeway Traffic

Accomplishments

This research has focused on driver behavior in the presence of large speed differentials between lanes. Our preliminary results have found that drivers' car following behavior not only depends on the lead vehicle in their lane, but also the speed of the adjacent lane. We have written a journal article based on this research that was recently accepted but will be part of next reporting period.

Products: No products at this time

Collaborations: No collaborations at this time

Impact: The findings enumerated in the accomplishments section are important because most car following models strictly depend on the leader in the same lane as the follower. So this work has found a previously unrecognized dependency. These findings should eventually lead to more robust microscopic traffic flow models, which in turn will improve the performance of all applications that depend on these models (from safety applications, to traffic control, to urban planning).

Changes or Problems: No problems at this time.

7.6. Smart Cities: The First-Mile Last-Mile Problem

An effort was undertaken to develop slow-moving platforms (single-person or 4-people vehicles) that would provide transportation for the mobility-impaired in a smart city. The effort has been initiated by the City of Columbus and later supported by an NSF Project (through its CPS: Smart Cities Program).
Products: Two vehicles were developed for a demonstration.
Collaboration: City of Columbus, NSF.
Impact: This project provides an opportunity to investigate Crash Imminent scenarios for slow moving platforms in dense pedestrian environments and related human factor issues. It also provides an opportunity to deal with the legal and administrative aspects of autonomous vehicle deployment, albeit in a traffic environment different than roadways.