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 save lives in doing so.**

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**.

Accomplishments:

- We have achieved partial success in networking multiple simulators to run the same scenario simultaneously without significant bandwidth limitations or time delay issues. The project has been slowed by the need to update software on all simulators in the UTC and to upgrade computer operating systems. Undergraduate student projects on the effects of background audio levels on driver attention and on the factors that promote aggressive driving are underway.
- We were able to use data from NHTSA's National automotive Sampling System Crashworthiness Data system (NASS-CDS) to document the most common injuries which occur during the three crash scenarios that are being focused on by the center. The data revealed that the most prevalent injuries from these crashes rank either in the minor or moderate category using the abbreviated injury scale (AIS). The focus has now shifted to using the Crash Injury Research and Engineering Network (CIREN) to further investigate the mechanisms of these injuries. Once we can document the specific injury mechanisms, we can focus on how to better protect occupants during these crash scenarios.
- The IUPUI team has been studying the combined automatic emergency braking (AEB) system and V2v system. The DSRC protocol has been augmented to handle the AEB messages in the V2V communication, all scenarios that can benefit pedestrians by the combined AEB-V2V system have been identified, and PreScan driving simulation for some of these scenarios have been implemented to demonstrate the advantage of the AEB-V2V system.
- We have gotten our data from the United States Congress from 1981-2014 processed and have started analyzing it. We have been focused on how autonomous vehicles and smart car technologies are discussed in the policy realm. What we have found is that while autonomous vehicles and the associated technologies will completely disrupt our current transportation regulations and assumptions of driver engagement, this has not yet made it to the policy discussions. That is, the policies and regulations surrounding these developments are most likely to be reactive, rather than proactive.
- 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 like Youtube does. It can also search clips of interest by attributes, and displaying temporal motion trajectories of vehicle and surrounding for data mining and accident analysis.
- For situations in which the autonomous driving suite (ADS) fails suddenly, we have developed a model that can be used both to predict drivers' responses to a sudden transfer of control from the ADS to the driver as a function of drivers' trust in automation, calibration, and skill level and to design an interface which can make the transfer as bumpless as possible. 2) For those situations in which the transfer of control can take place more slowly, we have designed scenarios on our driving simulator which can be used to determine the minimum time needed for such transfer to occur seamlessly when the driver is paying attention. 3) We have now given a vehicle on the RTI the automated driving capabilities it needs in order to undertake the above experiments.

Additionally, we have undertaken the following new initiatives and welcomed new faculty at CrIS UTC in this reporting period:

- CrIS UTC Seminar Series:
  Our spring seminars address a broad set of scientific and technical themes in automated and connected vehicle research. Guest speakers include
  - Lina Fu, Xerox Research Center, Rochester, New York
  - Tulga Ersal, University of Michigan, Ann Arbor, Michigan
  - Hitay Ozbay, Bilkent University, Ankara Turkey
- Global Cities Initiative:
  Project SMOOTH (Smart Mobile Operation: OSU Transportation Hub) will debut in June 2015 in Washington DC as part of the Global Cities Team Challenge. This activity, while not yet funded by the UTC, 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.
- New affiliated faculty:
  - Levent Guvenc, Professor, Mechanical and Aerospace Engineering
  - Bilin Aksun-Guvenc, Visiting Professor, Mechanical and Aerospace Engineering

Collaboration is at the heart of CrIS UTC, 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. In this past reporting period, the following collaborations have developed.

- Battelle
  Columbus, OH
- Knowlton School of Architecture
  The Ohio State University
  Columbus, OH
- City of Columbus
  Columbus, OH
- CISCO
  Dublin, OH
- Mid-Ohio Regional Planning Commission
  Columbus, OH

At Ohio State, collaborations with DURA and Toyota Information Technologies continue.

Collaborations were also established between UMass Amherst and: (a) investigators within the University of Iowa DOT Tier 1 UTC (SaferSim, of which we are also a member) in areas of mutual interest including bicycle/vehicle interactions and in-vehicle display of road signs and signals (University of Wisconsin) at meetings of the investigators at UMass Amherst in the fall and UPRM in the spring; (b) investigators in computer science at UMass Amherst working on semi-autonomous vehicles and transfer of control (UMass partnered on an NSF grant that was recently awarded); and (c) the Volpe National Transportation Systems Center (in PI Don Fisher's role as a Faculty Fellow).

Many CrIS UTC PIs attended the Transportation Research Board (TRB) Annual Meeting 2015 in January to become more familiar with state of the art research on automated vehicles and driver distraction detection.

Impact: At North Carolina A&T State University (NCA&T), the program has a tremendous impact in attracting future generation of scientist to STEM programs, both graduate and undergraduate students that are involved in transportation safety related problems. It also provides expertise to guide students and enhance collaboration at all levels with partner university participants, working on common projects.

These activities will broaden the collaboration among the participating institutions. Furthermore, it has created an immense interest among our undergraduate students pursuing graduate program in transportation safety related problems. Undergraduate students have their senior design project involving some of these. They are gaining fundamental knowledge in research relating to crash imminent safety and driving simulators in general. In addition, two undergraduate students are working on the driving simulator towards scenario authoring and data acquisition and processing. A great wealth of resources has been provided to the undergraduates in the ECE department as a result of our participation in this project.

Research on the driving simulator at UMass Amherst has led to additions to the MUTCD, directly or indirectly (flashing yellow arrow; advanced yield markings). We expect the research we are doing in the area of Crash Imminent Safety will impact the NHTSA guidelines for the performance measures used to evaluate the safety of in-vehicle devices **and future guidelines** that might apply to transfer of control with semi-autonomous vehicles.

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: *Curriculum Development*: CrIS UTC worked with the Center for Advanced Automotive Technology at Macomb Community College in Warren, Michigan to assist in the development of curriculum for advanced technician training. Educational Materials provided include training for sensors (multiple types like sonar and LIDAR), cameras, software, and systems integration, as well as lab manuals focused on advanced cruise control using LIDAR and driving simulator data collection/

Activity 2-*STEM Summer Program:* We have also begun planning to repeat the highly successful Women in Engineering (WiE) RISE camp "How to Train Your Robot" for high achieving high school students. Last year, students participated in a week-long workshop developed by graduate students and staff 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 will be extended to include more hands-on time for the 45 anticipated attendees.

Activity 3-*Undergraduate Independent Study:* One undergraduate student worked with LIDAR sensors and is developing an obstacle detection and navigation algorithm for vehicles moving at low speeds, such as material transport or people transport devices.

Activity 4-*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.

Activity 5-*Advanced Graduate Training:* 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 in autumn 2014. 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.)

Facilities and Experiments—K. Redmill

- We have begun the process of upgrading the operating systems and RTI driving simulation software to the most current version, which will facilitate and improve the interfacing, performance, and operation of the networked simulation activities.
- As part of the Global Cities Initiative, we are procuring and automating several small vehicles, such as golf carts and single-person mobility scooters, to explore first and last mile transportation issues using small-scale people movers. This activity, while not funded by the UTC, 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. This activity also requires an expansion of our wide-area communications equipment and capabilities.
- Undergraduate students, through the ECE capstone course, have designed and implemented drive-by-wire functionality on one of 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.
- Several students and researchers from the University Sao Paulo in Brazil were in residence at UTC facilities working on joint activity, image-based vehicle and pedestrian detection, which utilized UTC facilities and may be continued this summer.

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. 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 next few weeks we will re-establish the VPN connection with IUPUI and with UMass Amherst, and will proceed with getting joint simulation scenarios operative.

At the end of March of this year (2015), the University of Massachusetts Amherst (UMass) 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. (b) 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.

North Carolina A&T State University has purchased the SimVista driving simulator from RealTime technologies, and the student received training in October 2014. Three PhD students and two undergraduate students are working on projects 1, 2, and 3. Also, a team of four undergraduate students are working for two semesters toward their senior design project on "driver distraction detection" that is relevant to projects 1 and 2. Thorough literature reviews are done, and we are now working on conducting experiments and computer simulations on the following:

- **Scenario Authoring:** The scenario design and authoring tool which we are using is SimVista that is developed by Realtime Technologies Inc. for the desktop driving simulator. The SimVista uses Graphic User Interface (GUI), which allows for tile-based scenario design (as opposed to tedious text-based methods for others). Scenario control is achieved by two main groups of objects; sensors and markers. Sensors are mainly used to trigger action of other objects thereby controlling critical events whereas markers provide reference points for dynamic objects (mainly vehicles and pedestrians). Ambient traffic is automatically generated using the "bubble-based" algorithm. Two concentric "bubbles" are created around the human driver such that the border of the smaller bubble is just out of the driver's line of sight. New vehicles are placed randomly on the road network on the border of the larger bubble travelling toward the human driver.

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). 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 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, 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. Additional studies are in preparation.

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 has been challenging getting the simulators at Ohio State and UMass Amherst to talk with one another. We hope that with the upgrade to Version 3 of the RTI software this will no longer be a problem.

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 plan to run an experiment on our driving simulator to determine whether the model does indeed predict the optimized autonomous vehicle design with respect to the human operator.

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, a driver behavior classification approach was 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. Time series data of the target vehicle from both normal and dangerous driving data sets were analyzed to excavate decisive features that could set the dangerous behaviors apart from normal ones. The proposed classifier was verified with a test dataset and compared with an HMM classifier, and showed satisfactory results in reducing false negative rate of misclassification.

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.

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:

Liu, P., Kurt, A., Homaifar, A., Ozguner, U. (2015) Driver Behavior Classification using Decisive Feature Detection. Submitted to the *Proceedings of IEEE 2015 Intelligent Vehicle Symposium*, Seoul, Korea.

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

Seifemichael B. Amsalu, Abdollah Homaifar, Fatemeh Afghah, S. Ramyar, and Arda Kurt, "Driver Behavior Modeling near Intersections Using Support Vector Machines based on Statistical Feature Extraction" Intelligent Vehicles Symposium (IV) 2015. (Accepted in press)

M. Gorji Sefidmazgi, M. Moradi Kordmahalleh, A. Homaifar, and A. Karimoddini, "Switched Linear System Identification based on Bounded-Switching Clustering," the American Control Conference (ACC) 2015 (accepted in press).

D. Opoku, A. Homaifar and E. W. Tunstel, "RFID-Augmentation for Improving Long-term Pose Accuracy of an Indoor Navigating Robot," the 2014 IEEE International Conference on Systems, Man, and Cybernetics (SMC2014), pp. 796-801, 2014.

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: The main issue being faced in these projects is the lack of experimental data. The driving data set that was available from an earlier project was used for driver-model training with different methods at both OSU and NCA&T. These efforts showed that the limited nature of the data set in terms of number of drivers and hours impaired the researchers' ability to form statistically significant results. Therefore, the much larger data set at SHRP2 NDS is being pursued as described in the "Collaborations" section above. However, it was discovered that the access to this data set requires IRB certification from the individual institutions that are part of the CrIS UTC and the time it takes for the IRB certification process slightly delayed the progress towards some of the planned work and publications. The team used this time to explore different options that can be developed at a proof-of-concept level with the currently available data.

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 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).
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, submitted) (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.

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. 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 simulated driving transition situations that require transfers of control between the responsible human driver and ADS have been captured. The material is being integrated into three test scenarios.

Transition Scenario A) From bumper-to-bumper to open highway ahead.

1. **Initial transfer to ADS:** While in bumper-to-bumper traffic on four-lane divided highway, the participant begins by transferring control to the ADS. The transfer invokes instructions to the ADS to stay in lane and prevent vehicular collisions.
2. **Change in traffic situation:** Traffic begins to thin out and speed begins to pick up and move toward normal speed for that highway though still with heavy traffic.
3. **Re-authorization by / Transfer to responsible human:** As the traffic environment transitions to higher speeds and less traffic density, the human driver and the vehicle coordinate a re-authorization of control to adjust to the altered conditions.

Transition Scenario B) Upcoming highway exit.

1. **Initial transfer to ADS:** The responsible human driver transfers control to ADS authority for standard highway conditions.
2. **Change in traffic situation:** Driver is alerted to next event in trip plan — exit from highway is upcoming.
3. **Re-authorization by/Transfer to responsible human:** The human driver and the vehicle coordinate a re-authorization of control as the driver assesses the upcoming event.

Transition Scenario C) Contradictory models of the world.
Version - i) GPS routing signals use of an off ramp which is closed for construction.

1. **Initial transfer to ADS:** The responsible human driver transfers control to ADS authority for standard highway conditions.
2. **Change in traffic situation:** Driver is alerted to next event in trip plan — exit from highway is upcoming.
3. **Re-authorization by / Transfer to responsible human:** Conflict between ADS model (open ramp) and physical world (ramp is closed for construction).
   The human driver needs to see the conflict, transfer control or provide a new authorization.

Current and proposed semi-autonomous vehicles and self-driving functions combine multiple types of data from multiple sources (geolocation data from a GPS system, path clearance data from radar/lidar sensors, and optic flow data from cameras). Scenario C is designed to explore how the vehicle and driver might respond if information from those sources does not align or do not match the physical environment. The version (i) uses a conflict between GPS routing — open off ramp — but the ramp is blocked for construction. A second version of Scenario C will use a different kind of conflict where the multiple sensors provide conflicting data to the driver (e.g., we are currently investigating possibilities such as high center of gravity vehicles in traffic do not alert RADAR sensors and confuse rooftop cameras.

Version-ii) Conflict between multiple sensors.
Version ii of Scenario C will use a different kind of conflict where the multiple sensors provide conflicting data to the driver (e.g., we are currently investigating possibilities such as high center of gravity vehicles in traffic do not alert RADAR sensors and confuse rooftop cameras.

Vversion-iii) Loss of data channels.
Version iii of Scenario C will test the human driver ADS interaction when one type of data becomes unavailable or unreliable (snow obscures road lines, camera failure, GPS signal loss, etc.). The loss or degradation of a type of sensor changes the envelope previously authorized and requires driver involvement and either re- authorization or transfer of control back to the human driver.

Pilot testing of these scenarios is ready to begin shortly. Based on the pilot data, the method and stimuli will be modified for additional data collection.

Results to date:
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.

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 gets 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.

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

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.

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

Collaborations: NCA&T has been in touch with the UMass Amherst researchers who are also working on this project. They have been tremendous help towards our eye tracker integration. Furthermore, we are also in touch with the UMass Amherst and University of Wisconsin to work on driver-vehicle exchange. Driver distraction by in-vehicle devices such as navigation systems and analyzing the experiments results is the main focus of our collaboration.

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

a. Progress (Phase I)
   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 -
      - Lead vehicle stopped (Scenario 1): spine & extremities
      - Vehicle turning at a non-signalized junction (Scenario 2): thorax
      - Vehicle changes lanes (Scenario 3): head and face
   ii. 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.

b. Progress (Phase II)
   i. 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..)
      - 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.
      - 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).
   ii. The first step was to scan the CIREN database and pull cases that match the scenarios stated in Phase I.
      - The initial CIREN search revealed the following number of cases for each scenario
         a. Lead Vehicle Stopped – 6 cases
         b. Vehicle turning – 147 cases
         c. Vehicle changes lane – 10 Cases
      - It was decided to investigate Scenario 2 initially since it had the most cases to learn from.
   iii. To date 50 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 thoracic injuries (rib fractures, lung contusions and aortic tears) accounted for 41% of all severe injuries that occurred in this crash scenario.
      - Surprisingly though injuries to the brain accounted for 44% of all severe injuries, including all 4 of the fatal injuries reported.
      - Injuries to the abdomen accounted for the remaining severe injuries.
   iv. The leading mechanism of injury for all of these was contact with the intruding door structure. Many of these cases were belted but were in model year cars without side impact airbags.
   v. It will be interesting to further look at cases with airbags to see if the injury patterns are different.

c. Training or professional development

   i. We have introduced three students (Tim Gocha, Tanisha Kashikar & Lauren Eicharn) 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.

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

e. Plans for next period
   i. CIREN findings will be analyzed further and reported

Products:
Publications – Phase I findings from the NASS-CDS have been written and submitted to the Annals of Biomedical Engineering

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 was developed using 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.
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.
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 work on the second phase to transfer the pedestrian CIB model generated from PreScan environment to the Realtime Technology driving simulator. **Activity 2**. 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 transpotation 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).

During the second year, **UMass** plans to compare the driving simulator V2B collision warning systems with alternative roadway treatments (e.g., Dutch junction) in order to determine which, or both, function better than the current system.

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

Products: **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. A paper “Message Protocol for V2V-PCS DSRC,” authored by Xinyan Zhao, Stanley Chien, Lingxi Li, and Yaobin Chen, is written and will be submitted to 2015 IEEE International Transportation Systems Conference.
4. An invited presentation “Use PreScan to Simulate the Integration of V2V and PCS,” will be given to the PreScan Users Group Meeting on April 20, 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.
Proposals Based on the results in V2V-CIB simulation study, IUPUI collaborated with Delphi Electronics and Safety Systems to submit a joint proposal to CAMP LLC. for V2V platoon preliminary study.
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.
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 evaluating the safety improvement for V2V related pedestrian safety studies.

On the development of transportation workforce development: Three 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 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.
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. The dataset for the empirical policy research was processed so that analysis could begin. The dataset is from the U.S. Congress from 1981-2014. It includes all the Congressional debates, testimony, hearings, floor speeches, reports, and other documents from this period. In total, there are

approximately 5.5 billion words in the dataset. The method of analysis is text data analytics using computational and corpus linguistics. Papers are now being written from the dataset, including looking at how autonomous vehicles and vehicle safety are discussed in Congress.

2. With the empirical research successfully underway, preparations were begun to host several forums over the next year, bringing together different stakeholders to discuss the different technical and policy components of safety, crashes, and vehicle systems. The purpose of these forums is to both disseminate and gather information from policymakers, engineers, automotive manufacturers, suppliers, and drivers. In addition, I will be presenting a lecture on sustainable mobility at the end of April that will present the research.

What was learned?:
The research showed that autonomous vehicles are a small topic of conversation (this is not surprising). What is surprising is that the conversation is dominated by drones or unmanned aerial systems (UAS), where much of this technology comes from. When layered with vehicle safety, the conversation virtually disappears. That is, policymakers are not connecting autonomous vehicles to car safety in a meaningful way. In addition, when the larger issue of sustainable mobility was investigated, we found that there is virtually no connection between the conversations of sustainability (which focus mostly on wildlife and land management) and transportation/mobility. Autonomous vehicles are a disruptive technology to the regulatory and legal frameworks that we have for vehicle operations. 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: Currently, we are looking to hold the first forum presenting our research and engaging practitioners in October 2015.

Dissemination of Results: The first paper using the data has been submitted. 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 four papers submitted and under review. We are also planning on hosting the fall forum.

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

Products: Nothing to report

Collaborations: There are three collaborators working on this project: Dr. Betsy Barry, Dr. Clayton Darwin, and Suzanne Smith, JD. These three collaborators were visiting scholars at the Center for Automotive Research at the Ohio State University for a total of 10 months.

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 investigate various methods under the cognitive radio based communication paradigm to support Crash-Imminent Safety systems and develop new alternative methods to achieve high performance.

Accomplishments

1) During this reporting period, we continued our efforts to develop and assess various methods and approaches to enable cognitive radio-based communication for Crash-Imminent Safety Systems to achieve high availability and low latency. A simulation study was conducted 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
    a. Demonstrate the performance tradeoffs between spectrum sensing duration to improve confidence in estimations and the time dedicated to actual data transmission in vehicular cognitive radio networks.

   b. 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. While longer sensing durations lead to reduced data transmission opportunities, such reductions do not lead to significant negative impact on the overall delay and throughput performance. On the other hand, longer sensing durations significantly reduce the probability of collision with primary users. Hence, longer sensing durations are preferable since their advantages overweigh their disadvantages.
   b. The PU-Aware and Random selection schemes outperform the Sequential selection scheme in terms of CVN performance, while the Sequential selection scheme is more favorable for protecting PUs.

Dissemination: A conference paper is being prepared that outline our findings pertaining to this reporting period.

Next reporting period:

1) 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.
2) Design efficient centralized cognitive MAC protocols for vehicular cognitive radio networks.

Products:

You Han, Eylem Ekici, "Study of MAC Issues for Vehicle-to-Vehicle Safety Communications in Cognitive Vehicular Networks," in preparation, 2015

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.

Based on these observations, we are motivated to continue our efforts to find new ways to utilize available bandwidth such that vehicular networks and associated safety applications can deliver the expected performance levels.

Changes/Problems: Nothing to report

7.3 EEG and Lane Change Intent

Accomplishments

A low cost EEG sensor was tested in order to ascertain how useful its data might be for indicating a driver's intent to make a lane change in a simulated driving environment. From an initial evaluation of the data, records of eye gaze behavior are the most prominent indicators of lane change intent, though underlying EEG patterns as studied in medicine are also theoretically available over a sufficient amount of time. In order to detect lane change intent, two signal processing approaches are applied: a matched filter and a Naive Bayes Classifier. While it does seem that including EEG in a driver-sensing suite would add valuable information, results from the classification methods described here do not show any decrease in classification error with EEG data being added to the information of vehicle position, orientation, and velocity. Future experiments with a larger data set, direct comparison of EEG to existing eye-tracking methods, and perhaps better signal processing to reduce sensor noise would shed further light on the truth. The project can only continue if its scope is expanded.

Products: *Publications:*

D. Fredette, U. Ozguner, “EEG and Lane Change Intent in Driving Simulator,” CrIS Internal Report, August 2014.

Collaborations: Nothing to report.

Impact**:** Nothing to report.

Changes or Problems: Nothing to report.

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

Accomplishments

In this half year, our goals are to (1) design a driving video database to store Naturalist Driving Video. We achieved the retrieval of video clips with tagged attributes, and uploading new accident videos for preparing the resources of video data mining. (2) We have also succeeded in extracting the motion profile and road profile from video clips as indexes of big data of driving videos. (3) Analysis pedestrian walking behaviors in video as well as in motion profiles are also tackled. We are designing methods to identify pedestrians in a real time. The plan for next half year is to continue the database development and data analysis.

Products

1. Online driving video database named Drivingtube like Youtube is prototyped for hosting, displaying, and analyzing driving video (drivingtube.cs.iupui.edu).
2. Motion profile can be generated from video by an online tool for accident analysis.
3. Analyzed pedestrian motion in the video revealed unique motion characteristic and trajectories. Algorithms for pedestrian detection based on motion are being developed now. Initial results are published in a paper in IEEE ITSC 2014 at Qingdao, China. An improved algorithm is under development and the result is submitted to IEEE IV2015.

Collaborations

The data for database construction and testing are currently from the Toyota 110 Car Project in TASI Group, IUPUI, which is our first customer. The attributes of videos are for discriminating various traffic events related to driving and accident environment. Our results are shared with the entire TASI group. The database functions are designed to satisfy the needs of the team for data retrieval, batch downloading, motion profile extraction, and road profile extraction for the potential collision alarming, night illumination investigation, and vision algorithm design.

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 information, 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 this 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. It is our hope that we will submit a journal article based on this research during the forthcoming 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.