C^2M^2 NEWS

December, 2018

USDOT CENTER FOR CONNECTED MULTIMODAL MOBILITY

AN INNOVATION CENTER FOR TRANSFORMING MULTIMODAL TRANSPORTATION THROUGH CONNECTIVITY, DATA ANALYTICS, AND AUTOMATION

In this issue:

Editors: Dr. Eric Morris, Dr. Mizanur Rahman and Charlotte Ryggs.

Letter from the Director

Dr. Mashrur "Ronnie" Chowdhury

Welcome to the fourth edition of USDOT Center for Connected Multimodal Mobility (C^2M^2) newsletter. This season, as we wrap up our first year as a center, we are focusing on the impact that we have had on both our affiliated partner institutions and the communities we serve.

On October 24 and 25, 2018, we hosted the 6th Annual UTC Conference for the Southeastern Region at the Madren Conference Center in Clemson, South Carolina. This conference featured Carla Bailo of the Center for Automotive Research as the keynote speaker. She spoke on creating safer, more accessible, and better-connected smart cities, as well as the future of mobility. In addition, this conference featured a state Department of Transportation (DOT) Panel, research presentations by students and faculty, and a connected and automated vehicle (CAV) technology demonstration. In conjunction with this event, we hosted our second Advisory Board meeting. Our board members, who include diverse participants drawn from various transportation organizations, provided valuable guidance to our Center administrators regarding our technology transfer plan, securing matching funds for our center, and our plans to make our center more self-sustaining financially.

In this quarter, we selected 12 research projects for our next round of funded research. These cover a wide array of topics including autonomous vehicles for disaster relief; security for connected vehicles; bike share networks; railway emergency management; distracted walking; and unmanned aircraft for surface transportation management. Several of these projects are already underway, and the remainder will start soon. We have also given multiple technology demonstrations for both students and transportation professionals, showcasing our research to over 700 people. Further, we have seen the very first of our C^2M^2-sponsored students graduate, three with masters' degrees and one with a doctorate.

We are excited to continue our quest to make multimodal transportation the best it can be. We are developing new technology, studying the ways in which this technology can serve businesses, governments, and the public, and educating and training students and professionals to carry the torch forward. We hope you will continue to accompany us on our journey.

Dr. Mashrur "Ronnie" Chowdhury

6TH ANNUAL UTC CONFERENCE FOR THE SOUTHEASTERN REGION HIGHLIGHTS

On October 24 and 25, 2018, C²M² hosted the 6th Annual University Transportation Centers Conference for the Southeastern Region. It was held at the Madren Conference Center in Clemson, South Carolina. This conference featured Carla Bailo of the Center for Automotive Research as a keynote speaker, a state DOT Panel, research presentations by students and faculty with prizes for the top three student poster presentations and the top three student oral presentations, and a CAV technology demonstration.

Keynote speaker Carla Bailo, President and CEO of Center for Automotive Research (CAR), presenting

Dr. Chowdhury giving opening remarks

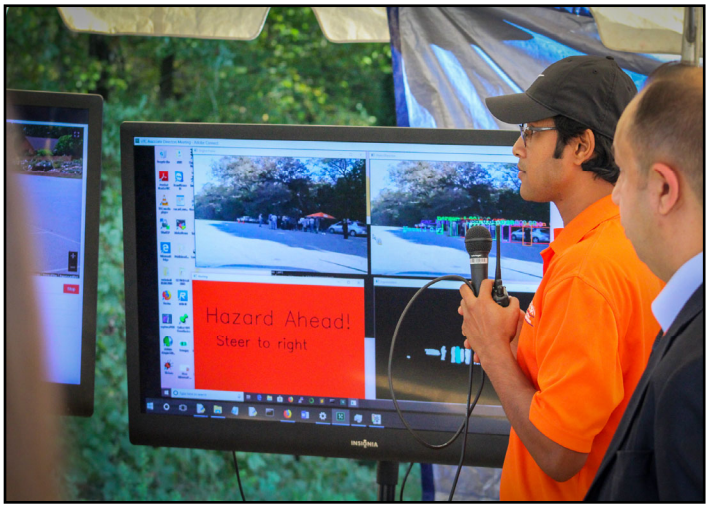
Students presenting their posters

Dr. Chowdhury, C²M² Director, and Ms. Charlotte Ryggs, C²M² Program Coordinator, led the planning committee, which was made up of UTC directors from the Southeastern Region, with representatives from the Southeastern Transportation Research, Innovation, Development and Education Center (STRIDE); the University of Florida Transportation Institute (UFTI); the Center for Urban Transportation Research (CURT); and other representatives from partnering schools.

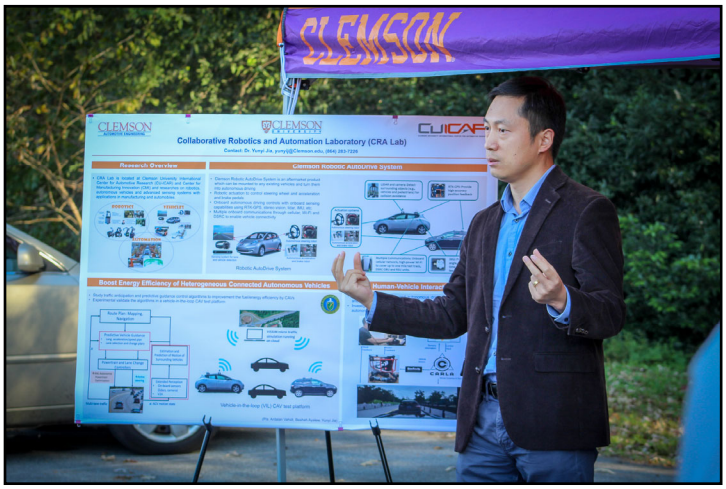
UTC conference participants

Photo credit: Isaiah Del Campbell

6TH ANNUAL UTC CONFERENCE FOR THE SOUTHEASTERN REGION HIGHLIGHTS (CONT'D)



Dr. Chowdhury and his team demonstrating connected and autonomous vehicle technologies



Dr. Yunyi Jia demonstrating an autonomous vehicle

Virtual traffic signal for connected autonomous vehicles demonstration

Winners of best student poster and oral presentations

2018 C²M² FUNDED RESEARCH PROJECTS

In June, 2018, C²M² sent out a call for proposals (CFP) to 21 researchers at our five partner institutions, launching our 2018/2019 round of funded projects. This CFP was also announced on our website and twitter feed. Collaboration between consortium members was strongly encouraged and several new principal investigators (PIs) received funding to increase the breadth of research topics funded by our center.

Fourteen research proposals were submitted to C²M² for potential funding, with six new PIs submitting along with eight returning PIs. The proposals covered a range of new topics.

Proposals were sent out for blind review by at least three industry professionals from academia and public and private agencies. The C²M² Director and Associate Directors—Drs. Chowdhury (Clemson University), Comert (Benedict College), Huynh (University of South Carolina), Michalaka (the Citadel) and Mwakalonge (South Carolina State University)—evaluated the proposals and reviews. Twelve research projects were selected for funding. Five are led by Clemson University, two are led by SCSU, four are led by USC, and one is led by the Citadel. Benedict College will collaborate on ten of the selected projects.

Assessing Potential of Bike Share Networks and Active Transportation to Improve Urban Mobility, Physical Activity and Public Health Outcomes in South Carolina

Lead Principal Investigator – William J. Davis, The Citadel
Co-Principal Investigators – Kweku Brown, The Citadel; Daniel Bornstein, The Citadel; Morgan Hughey, College of Charleston; Dimitra Michalaka, The Citadel; Nathan Huynh, University of South Carolina; Andrew Kaczynski, University of South Carolina

Description: There is need for evidence-based research about how, when, where, and why people undertake active travel, like bicycling and walking, and about how the built environment and infrastructure may or may not accommodate active travel. As stated in the National Physical Activity Plan, transportation and public health entities should collaborate to "improve and expand existing data collection sources to assess active transportation patterns and trends that include local-area data." Charleston, South Carolina has the conditions necessary to promote active travel, such as supportive stakeholders and a walkable built environment, as well as the tools to study the conditions under which active travel may thrive. This research will conduct a case study on active travel in Charleston, focusing on issues such as route conditions and the use of bike share programs to better understand how Charleston's built environment is meeting the health, physical activity, and transportation needs of the community.

Intellectual Merit: Qualitative, quantitative, and geospatial methods will be used to evaluate active transportation, physical activity, and health outcomes in Charleston, South Carolina.

Broader Impacts: Research results will be beneficial to communities which are undertaking active transportation and bike share initiatives to improve mobility, reduce congestion, promote sustainability, increase levels of physical activity, and bring about desirable public health outcomes.

Technology Transfer: The research team will engage local officials, decision makers, and community stakeholders by communicating its data analysis and results, for example through infographics, formal meetings, and a guidebook. Findings will also be published and presented in national engineering and city planning forums, and will be disseminated to municipalities and other stakeholders via strategic technology transfer channels.

Enhanced DSRC Security

Lead Principal Investigator – Richard R. Brooks, Clemson University
Co-Principal Investigator – Gurcan Comert, Benedict College

Description: Dedicated short-range communication (DSRC) is becoming an accepted wireless connected mobility standard. However, DSRC development groups report that DSRC protocols, applications and stacks are not mature. Many applications using the DSRC protocol have not been adequately tested and verified. Industry perceives a need for security validation tools for DSRC applications. Researchers at both Clemson and Benedict College have done research on connected mobility applications using DSRC. For this project, they will leverage that experience to develop a new tool that supports the secure design and security testing of DSRC applications.

Intellectual Merit: The research team will develop a penetration testing tool that automates the vulnerability discovery process for 802.11p-based DSRC protocols.

Broader Impacts: This project will improve cybersecurity for a technology that may play an important role in allowing vehicles to communicate with each other, and with infrastructure, such as traffic signals and roadside units, in the connected transportation world of the future.

Technology Transfer Plan: The research team has an agreement with Kaspersky Labs and the International Transport Innovation Center (ITIC), Greenville, SC to test the concepts it develops in their security labs. The goal is to create and implement penetration testing tools for connected vehicle applications that are easily integrated into their offerings.

Framework for Accommodating Emerging Autonomous Vehicles

Lead Principal Investigator – Burak Eksioglu, Clemson University
Co-Principal Investigators – Matthias Josef Al Schmid, Clemson University; Gurcan Comert, Benedict College; Nathan Huynh, University of South Carolina

Description: The emergence of connected and autonomous vehicles (CAVs) and their potential for transforming freight transportation is the motivation for this project. CAVs will enable autos and trucks to "platoon," traveling closely together on highways in order to maximize travel speed, reduce fuel consumption, and reduce congestion by cutting down on the road space each vehicle occupies. However, research related to vehicle platooning has been conducted for several decades now, the majority of this research focuses on the control aspect of vehicles. In addition, a large portion of the research has addressed single platoons or individual vehicles in a platoon. The coordination and optimization of platoons over a large-scale, real-world road network has not been addressed adequately. One of the reasons for this gap is the lack of a central place to find a current location and eventual destination information for vehicles in a platoon, or those that may join a platoon. Another problem is the lack of a global coordinator with the authority to suggest routes to individual vehicles in ways that will provide them with platooning opportunities. This study aims to fill these gaps in the research literature.

Intellectual Merit: The work will advance knowledge through the development of: 1) novel mathematical models and agent-based simulations to represent the flow of CAVs that may take part in platoons in a transportation network, and 2) innovative solution algorithms to solve these large-scale optimization problems.

Broader Impacts: The findings will be of use for developing policies to reduce traffic congestion and fuel consumption, and improve safety and travel time reliability, in a world of CAVs.

Technology Transfer Plan: The research team will coordinate efforts to disseminate its results with South Carolina Logistics. It will organize research seminars as part of the ongoing seminar series at Clemson's International Center for Automotive Research (CU-ICAR). It will also conduct programs to train and educate underrepresented students, and organize workshops for teachers.

Unmanned Aircraft Systems' (UAS) Impact on Operational Efficiency and Connectivity

Lead Principal Investigator – Joseph M. Burgett, Clemson University
Co-Principal Investigators – Dennis Bausman, Clemson University; Gurcan Comert, Benedict College

Description: The overarching goal of this research project is to help launch an effective unmanned aircraft system (UAS) program at the South Carloina Department of Transportation (SCDOT). The research team has already assisted with the development of the SCDOT UAS Policy Statement, and shadowed a bridge inspection team in SCDOT's District Seven. The team will be providing logistical information to SCDOT about how other state DOTs have set up their programs. It will also conducted experiments testing a state-of-the-practice UAS in collaboration with a SCDOT bridge inspection team. The experiments will evaluate how a UAS can reduce bridge inspection time and cost by providing additional tools to inspectors. This will reduce the cost of design with more current as-built/as-is documentation, and ultimately make our infrastructure safer and better prepared for natural disasters.

Intellectual Merit: This study will help enable a UAS to provide real-time infrastructure assessment in a fraction of the time it takes using traditional methods during natural disasters.

Broader Impacts: This project will help increase connectivity for field-to-office information flow, improving the safety of our bridge infrastructure and reducing the cost of maintaining it.

Technology Transfer Plan: This project will be jointly funded by the SCDOT, ensuring an immediate transfer of technology for field application. The findings will be documented in a report submitted to the SCDOT as well as articles submitted for publication in peer-reviewed journals and conference proceedings.

Assessment of Autonomous Vehicle Sharing for Evacuation and Disaster Relief

Lead Principal Investigator – Pamela Murray-Tuite, Clemson University
Co-Principal Investigators – Nathan Huynh, University of South Carolina; Gurcan Comert, Benedict College

Description: This project will explore how privately owned Autonomous Vehicles (AVs) may be used in pre-impact assisted evacuation and post-impact relief distribution in times of disaster. It will begin by investigating whether the public in South Carolina would be willing to share their future AV's to assist with evacuation, as well as post-impact relief distribution in cases where trucks may be unable to travel to particular destinations due to infrastructure damage and height or weight limits which would be a concern for larger vehicles. The research team will identify and explore the public's concerns about such a program, as well as other potential barriers and limits to sharing. This initial exploration will help determine the feasibility of AV sharing in times of crisis.

Intellectual Merit: The overall goal of this project is to help prepare transportation and emergency management agencies for the future when AVs are more prevalent. It will be the first to gauge public opinion about this novel strategy for disaster management.

Broader Impacts: A system of sharing AVs in times of crisis would reduce the government's cost of assisted evacuation, save lives, and improve humanitarian relief distribution, all by engaging citizens to actively help their "neighbors."

Technology Transfer Plan: The project findings will be disseminated through a webinar for practitioners, the research community, and the public.

Security of Connected Vehicles via Sandboxing Against False Data Injection Attack

Lead Principal Investigator – Pierluigi Pisu, Clemson University
Co-Principal Investigator – Gurcan Comert, Benedict College

Description: This project will develop a resilient control framework for managing information flows for CAVs. More specifically, it will create a cloud-based sandboxing technique that will allow CAVs to safely operate even in corrupted conditions when malicious data is injected into the communication network. The technique will also account for communication delays, real-time computational constraints, and opportunistic behavior and uncertainties in the localization of non-connected vehicles (non-CVs). The project will focus on both urban and extra-urban driving scenarios, and on heterogeneous traffic conditions (60% or higher CAV technology penetration).

Intellectual Merit: The research team will develop a cloud-based control-oriented technology solution for CAVs that utilizes infrastructure information, along with a traffic model to detect cyber-attacks consisting of false information injected into the CAV communication system.

Broader Impacts: The technology that will be developed may play an important role in integrating smart cities' and regions' infrastructure services and components by accelerating the introduction of CAVs and vehicle-sharing services.

Technology Transfer Plan: Both the software and the algorithm the team develops will be licensed to the private and public sectors.

Tool to Access Effectiveness of Intermodal Facility Location and Carrier Collaboration

Lead Principal Investigator – Nathan Huynh, University of South Carolina
Co-Principal Investigators – William Ferrell, Clemson University

Description: This project will explore fundamental elements of transportation hub location, freight consolidation execution within a local geographic region, and the integration of connected multimodal mobility within the context of on-demand collaborative logistics systems. This will be done on a state level with South Carolina serving as the case study.

Intellectual Merit: The goal of this research is to reduce inefficiency in the logistics sector, assist in the transition to future logistics systems, and develop ideas that will be integral to future logistics systems. It will do so by focusing on connectivity and interoperability as facilitators for on-demand, collaborative logistics systems.

Broader Impacts: The ultimate aim is to better understand and inform investment decisions that can facilitate and coordinate a transition from the current logistics strategy to one that is more efficient and has less impact on society and the environment. This will save on money, time, emissions, road space, and fuel in the logistics system, benefitting businesses, governments, and consumers.

Technology Transfer Plan: The models and tools developed by the team will be available for use by the South Carolina Department of Transportation, Council of Governments, and Department of Commerce. Video tutorials will be developed and shared with interested stakeholders.

Data-Driven Multimodal Transportation Energy Consumption Prediction and Analysis Framework for Sustainable Transit and Transportation Planning

Lead Principal Investigator – Yuche Chen, University of South Carolina
Co-Principal Investigators – Gurcan Comert, Benedict College; Nathan Huynh, University of South Carolina

Description: Transit agencies/mobility providers usually utilize time-based and distance-based link-level information in planning their routes and schedules. However, average energy consumption rates (e.g., gallons per mile, kWh per mile) on links of a road network are seldom considered in these planning activities. The major reason is a lack of accurate energy consumption information. For sustainable transportation planning, gathering and analyzing data on energy consumption, particularly considering new alternative vehicle technologies, is needed.

Intellectual Merit: The goal of this project is to develop a high-resolution system-level transportation energy data analysis and prediction framework for transit schedule/operation planning, aimed at improving energy efficiency.

Broader Impacts: The outcomes of this project will be utilized by regional planners or transit/mobility service providers for route/schedule planning and traveler guidance system integration. The goal is to reduce energy consumption, which will benefit transit agencies, transit patrons, and the public.

Technology Transfer Plan: The tangible products of this project will be: 1) tools to estimate link-level transportation energy consumption, and 2) an energy consumption density map. Results will be made available for use by transit agencies/mobility providers.

Data Fusion to Improve the Accuracy of Multi-Modal Traffic Counts

Lead Principal Investigator – Robert L. Mullen, University of South Carolina
Co-Principal Investigators – Gurcan Comert, Benedict College; Nathan Huynh, University of South Carolina; Balaji Iyangar, Benedict College

Description: Current traffic counting systems often only measure one transportation mode accurately. For example, loop detectors cannot count pedestrian traffic. The research team will explore data fusion to improve the reliability of traffic counting technology by using multiple sensing methods. Specifically, the team will augment a computer vision based counting system with information extracted from other sensing technology (e.g., tube pressure signals). Additional data may also originate from magnetic loops, radar, vibration, and laser measurements. The project will use the raw data from the augmented sensors (with transient tube pressure signals) to count and classify mode types (FHWA 13 types, bicycles, and pedestrian traffic).

Intellectual Merit: This project will evaluate the use of combined raw data from the tube-based vehicle counting/classification method and an integrated artificial neural network (ANN) to classify vehicle types with better accuracy than existing methods using data from one type of sensor.

Broader Impacts: Improved data on the multi-modal movement of people and freight will provide transportation planners with better quantitative information on use of the existing system.

Technology Transfer Plan: This research will be generating an implementation-ready hybrid traffic data collection tool for DOTs.

Intelligent Camera-Aided Railway Emergency System (i-CARES)

Lead Principal Investigator – Yu Qian, University of South Carolina
Co-Principal Investigators – Yi Wang, University of South Carolina; Dimitris Rizos, University of South Carolina

Description: Trespass casualties represent roughly 70% of accidents on railroad right-of-way (ROW) in North America. Ironically, more than 60% of collisions occur at crossings with automatic warning systems, and 34.7% occur at crossings that have flashing lights and gates. This is in part because there are several shortcomings with the existing grade crossing warning system, including that the flashing and gate arm only indicate an approaching train without information about its estimated arrival time. To improve safety at crossings, the research team will develop the first-ever Intelligent Camera-Aided Railway Emergency System (i-CARES). i-CARES will make use of image-based monitoring and surveillance, quantitative situational awareness assessment, and direct “two-way” communication and information sharing. i-CARES will offer automatic fault detection and notification for CBM, as well as imagery evidence for trespassing violations (similar to the Electronic Police Reports Online (ePRO) system).

Intellectual Merit: This project will develop a first-of-its-kind, low-cost, field-deployable system to improve multimodal safety at railroad grade crossings.

Broader Impacts: i-CARES will benefit all travelers, including pedestrians, vehicles, and trains. It will save lives and avoid property damage in an efficient and economical way.

Technology Transfer Plan: The outcomes from this project will be able to be used to develop prototype devices that can be installed at railroad crossings in the near future.

Attribution Theory and Collisions at Intersections

Lead Principal Investigator – Judith L. Mwakalonge, South Carolina State University
Co-Principal Investigator – Gurcan Comert, Benedict College

Description: An automobile driver is seldom alone on the road. Whenever there is another vehicle–even only one –on or approaching the road on which the driver is travelling, the future behaviors of the other driver must be guessed at, and the probabilities of the possible maneuvers of the other car estimated. Understanding driver expectations about what other drivers plan to do is essential for understanding how and why accidents happen, which in turn can lead to better countermeasures to prevent them.

Intellectual Merit: This research will provide an outline for a range of driver expectations at intersections, including driver indications, stop-or-go decisions, performance and design of intersection traffic control devices, and turn maneuvers.

Broader Impacts: The research findings will help improve driver behavior models in traffic simulation software and the design of the mental behavior of automated vehicles.

Technology Transfer Plan: The research team will share its findings through participation in regional, national and international conferences and research competitions, and by the publication of articles related to the research.

Evaluation of Before- and After-Measures to Curb Distracted Walking

Lead Principal Investigator – Judith L. Mwakalonge, South Carolina State University
Co-Principal Investigators – Jae Dong Hong, South Carolina State University; Gurcan Comert, Benedict College

Description: Distracted walking is a major safety concern that causes fatalities and injuries worldwide. However, it has not received nearly as much attention, policy focus, or effective interventions as distracted driving. As the use of mobile devices continues to become more ubiquitous in our personal and professional lives, the incidences of injuries and fatalities involving distracted pedestrians are expected to rise. Thus there is a need to develop measures to reduce the impacts of distracted walking to improve the safety of pedestrians and other road users. This research will propose and evaluate such measures.

Intellectual Merit: This research will increase our understanding of distracted walking and will develop novel means of preventing it.

Broader Impacts: The findings of the research will provide important information to the public on the negative safety impacts of distracted walking, and strategies for public agencies to discourage and manage it.

Technology Transfer Plan: The research findings will be presented to transportation agencies, public officials, and enforcement agencies.

UPDATE OF C²M² SPONSORED PROJECTS

As we move into our second year, the researchers conducting C²M² funded projects from last year's call for proposals are close to submitting their final reports. Below are some highlights from their projects.

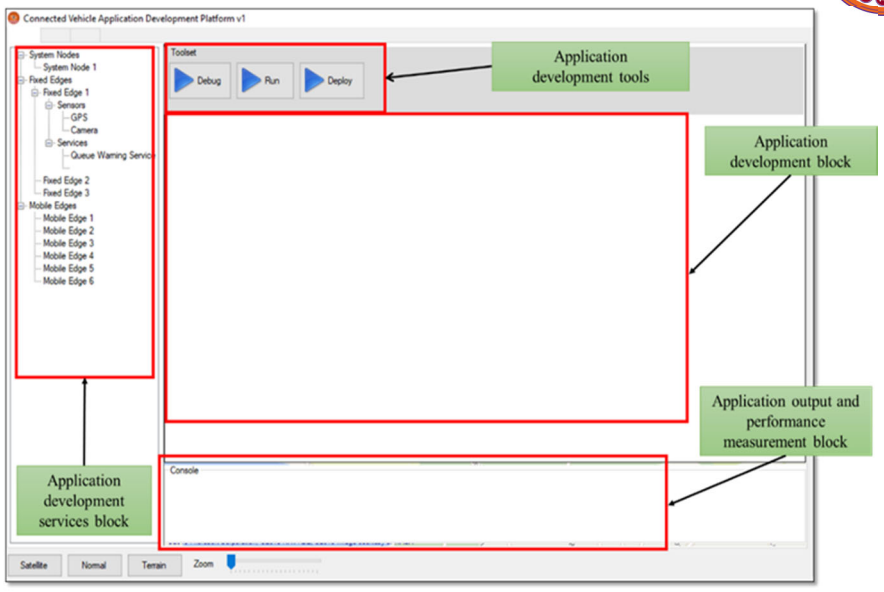
Foundation Project: Development of Cyber-Physical Systems (CPS) for Connected and Autonomous Vehicles (CAVs)

Lead Principal Investigator – Mashrur "Ronnie" Chowdhury, Clemson University

Sub-project 1: Connected Vehicle Applications Development Platform (CVDeP)

Developers need a platform to build, test, and debug CV applications, such as safety, mobility, and environmental applications, in an edge-centric Cyber-Physical System (CPS). The major challenges are: 1) to enable developers to collect, process, and distribute data while running multiple CV applications concurrently in real-time in different edge layers; and 2) to ensure the security of the platform and applications while maintaining their scalability. The research team has developed and evaluated a scalable and secure CV application development platform (CVDeP) for this purpose. CVDeP ensures that the CV applications meet the latency requirements imposed by other applications. The research team conducted a case study to evaluate the efficacy of CVDeP using two CV applications (one safety and one mobility application) and validated it through field evaluation at the Clemson University Connected and Automated Vehicle Testbed (CU-

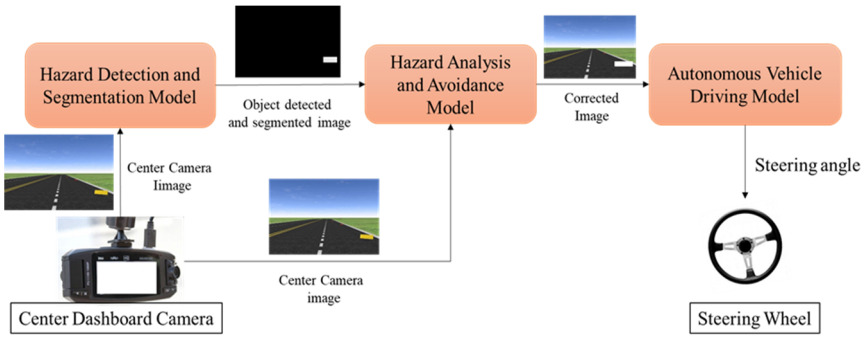
CAVT). The analysis proves the efficacy of CVDeP, which satisfies the functional requirements (e.g., latency, throughput) of a CV application while maintaining the scalability and the security of the platform and applications.



Graphical interface of the Connected Vehicle Application Development Platform (CVDeP)

Sub-project 2: Vision-Based Navigation of Autonomous Vehicles (AVs) in Roadway Environments with Unexpected Hazards

The research team has developed a unique AV hazard detection and maneuvering approach in its Cyber-Physical Systems laboratory. This can improve safety by navigating AVs during unexpected roadway events, whether caused by deliberate action (e.g., roadblocks) or unintentionally (e.g., debris). The researchers first created a hazardous roadway environment (with both intentional and unintentional hazards). These hazards have the potential to compromise the deep neural network (DNN)-based system of an autonomous vehicle, producing an incorrect vehicle navigational output such as the wrong steering wheel angle, which in turn can cause crashes. Next, the team developed an approach based on object detection and semantic segmentation to mitigate the adverse effects of this hazardous environment and help the AV to navigate safely around such hazards. They find the DNN-based model with hazardous object detection and semantic segmentation improves the ability of an AV to avoid potential crashes by 21% compared to the traditional DNN-based autonomous driving system.

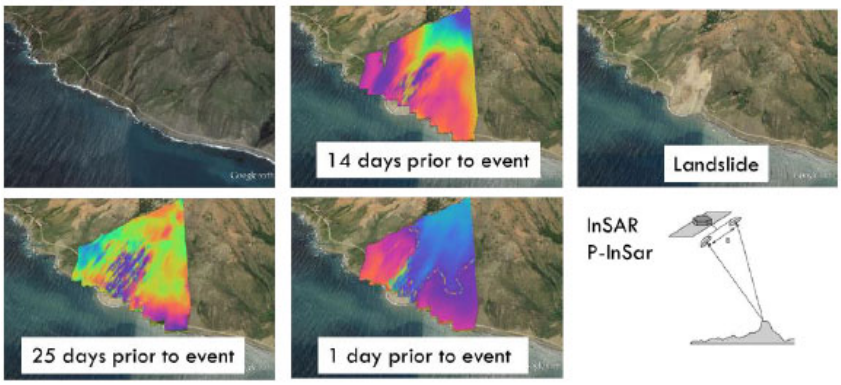


Framework of an autonomous vehicle driving in an unexpected hazard environment

Railway Right-of-Way Monitoring and Early Warning System (RailMEWS) Based on Satellite and Aerial Imagery

Lead Principal Investigator – Dimitris Rizos, University of South Carolina
Co-Principal Investigator – Robert Mullen, University of South Carolina

In this Phase-I one-year project, the research team conducted feasibility studies for the development of tools that will lead to a Railway Right-of-Way Monitoring and Early Warning System (RailMEWS). The team processed satellite radar images using the Interferometric Synthetic Aperture Radar (InSAR), Differential Interferometric Synthetic Aperture Radar (DInSAR) and Persistent Scatterer Interferometric Synthetic Aperture Radar (PSInSAR) methods, as implemented in open source software. The results showed that it is possible to detect changes in soil moisture content and subsidence of the ground surface that could lead to potential failures along the right-of-way of highways and railways. In one example study shown here, the team collected historic satellite images in the period before and after a massive landslide on California's Highway 1. In the 14-day period before the event, disturbances in the phase of the signal were observed that indicated changes in the ground moisture content.

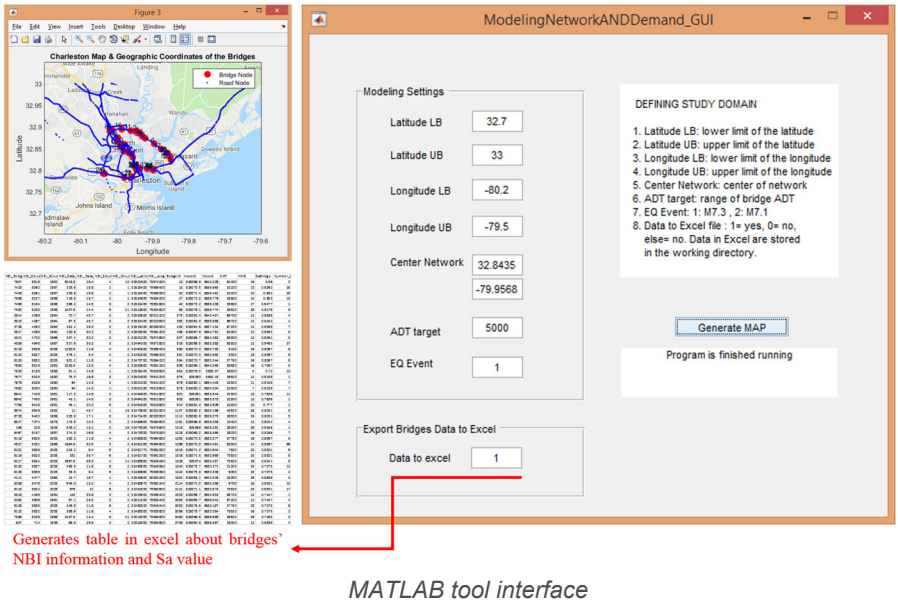


Case study of Differential Interferometric Synthetic Aperture Radar (DInSAR)

Improved Resiliency of Transportation Networks Through Connected Mobility

Lead Principal Investigator – Paul Ziehl, University of South Carolina
Co-Principal Investigators – Robert Mullen, University of South Carolina; Weichiang Pang, Clemson University

Most of the bridge retrofit program, including the expected damage method used by the Federal Highway Administration (FHWA), ignores aspects of bridges' importance, such as their centrality, historical significance, and traffic capacity. Bridges' centrality measures the influence a bridge has on the flow of the traffic. Historical significance, as coded in NBI, considers the value of the bridge due to its association with significant events or circumstances. This research has developed a tool that combines these three characteristics with the expected damage to the bridge to optimize network performance. It has created a tool which considers a directed path (dipath) and travel distance for maximizing traveling capacity and minimizing retrofitting cost. Instead of having to rely on multi-platform software integration, the tool runs on a single platform, Matlab, which results in efficiency with respect to software accessibility and computational time. The functionalities include network and seismic demand visualization, with the development of fragility curves and Monte Carlo simulation for estimating the failure probability of bridges. One of the main goals of the research is to transfer this technology, with the US Department of Transportation as a potential target user.

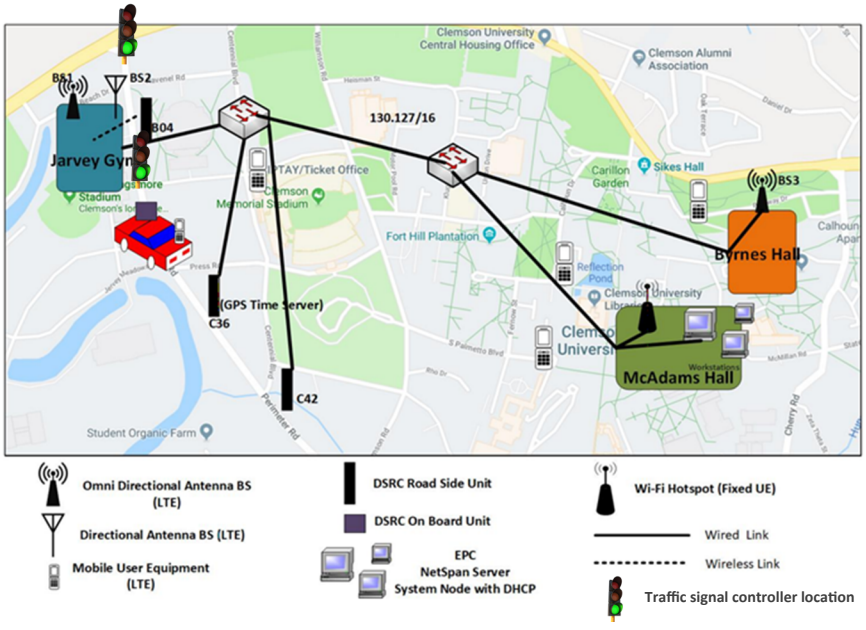


MATLAB tool interface

Uncertainty Quantification of Cyber Attacks at Intelligent Traffic Signals

Lead Principal Investigator – Jim Martin, Clemson University
Co-Principal Investigator – Gurcan Comert, Benedict College

In this research, the team developed middleware that is an application software development kit appropriate for Wireless Access in Vehicular Environments (WAVE) , Unmanned Aerial Vehicle (UAV) swarms, and roadway transportation infrastructures, such as traffic signal controller and roadside data infrastructure, application systems. It includes a collection of mobile network performance measurement tools, which are used to evaluate vehicle-to-infrastructure communication performance on the Perimeter Road, Clemson, South Carolina. In addition, the team investigated the efficacy of two change point models, Expectation Maximization (EM) and Cumulative Sum (CUSUM), for real-time vehicle -to-Infrastructure (e.g., vehicle-to-traffic signal controller infrastructure) cyber attack detection in a connected vehicle environment. To prove the efficacy of these models, the team evaluated them for three different type of cyber attacks—denial of service (DOS), impersonation, and false information—using basic safety messages (BSMs) generated from CVs through simulation. Results revealed that EM and CUSUM could detect DOS, impersonation, and false information with an accuracy of 99%, 100%, and 98%, and 100%, 100% and 98%, respectively.

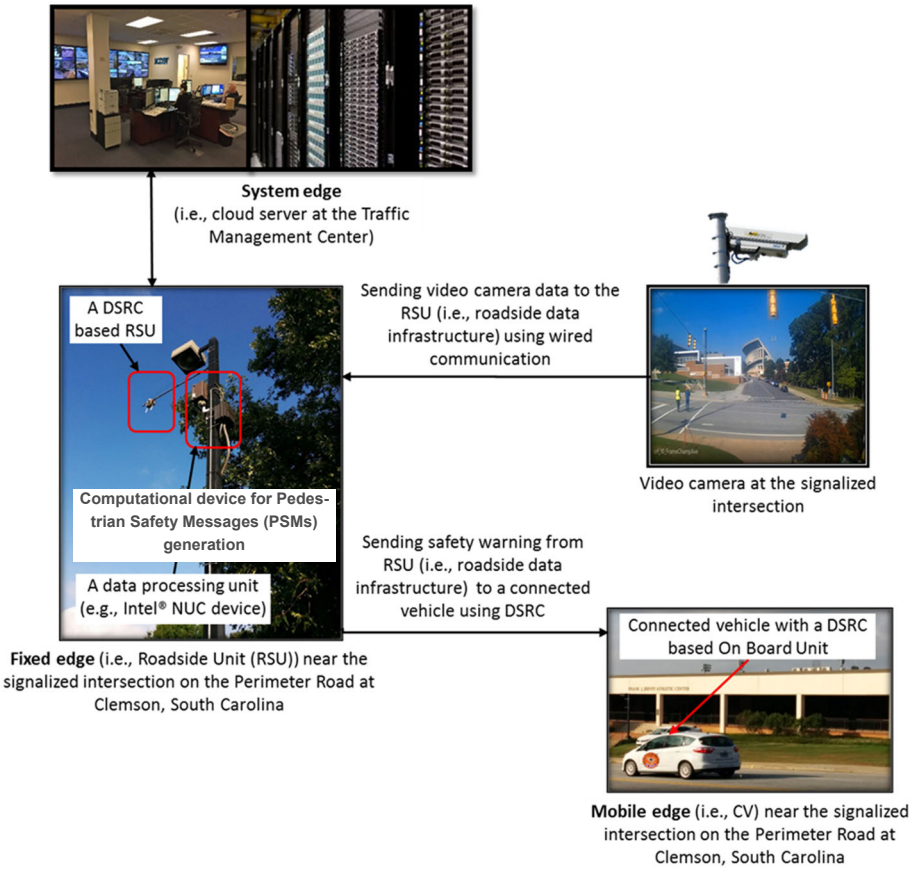


Experimental set-up for cyber attack detection on Perimeter Road, Clemson, South Carolina

Real-Time and Secure Analysis of Pedestrian Data for Connected Vehicles (CVs)

Lead Principal Investigator – Amy Apon, Clemson University
Co-Principal Investigators – Mashrur "Ronnie" Chowdhury, Clemson University; Gurcan Comert, Benedict College

Vehicle-to-Pedestrian (V2P) communication can significantly improve pedestrian safety at a signalized intersection. However, it is unlikely that pedestrians will carry a low latency communication-enabled device and activate a pedestrian safety application all the time. Because of this limitation, multiple traffic cameras at signalized intersections can be used to accurately detect and locate pedestrians using deep learning. The infrastructure can then broadcast safety alerts related to pedestrians to warn CVs near signalized intersections. However, the unavailability of high-performance computing infrastructure at the roadside, and limited network bandwidth between traffic cameras and the computing infrastructure, limits the ability of real-time data streaming and processing for pedestrian detection. In this study the research team developed a novel approach using vision-based sensor fusion and deep learning that can generate Pedestrian Safety Messages (PSMs) to improve the intersection pedestrian safety. The team also validated its method of generating PSM messages using a field experiments in a CV environment.



Field experiments of Pedestrian Safety Message (PSM) generation

Assessing the Experience of Providers and Users of Transportation Network Company Ridersharing Services

Lead Principal Investigator – Eric A. Morris, Clemson University
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Uber and Lyft offer services called UberPool and Lyft Shared (formerly Lyft Line) which connect drivers and passengers in real time so that passengers with similar origins and destinations can share rides. This has the potential to get cars off the road by increasing the occupancy of Uber and Lyft vehicles. But there are problems with these services, including driver frustration with their low compensation and rider dissatisfaction with unpredictable and sometimes lengthy deviation from their routes when they are matched with other travelers. Further, taking Pool or Shared involves being closely confined with strangers for an extended period of time, a new social dynamic in transportation which may or may not be viewed as pleasant. This project investigated the UberPool and Lyft Shared experience for drivers and riders in two ways. First, the researchers completed a study of Twitter commentary about the services. Second, they conducted a survey on driver and rider attitudes. Results show, among other things, that the social experience involved with sharing rides has some minuses; for example, many express frustration with the behavior of other passengers, and many who use Uber and Lyft but do not used the shared services cite safety concerns about sharing with others as a major reason they do not use the services. However, online commentary suggests that passengers enjoy sharing humorous stories about the foibles of those with whom they ride, and often enjoy meeting others. Thus sharing rides may have both positive and negative social impacts.

Infrastructure and Policy Needs for Personal Electric Mobility Devices (PEMDs) in the Connected Vehicle World

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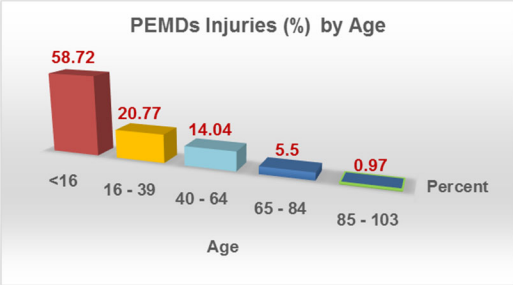

PEMDs related injuries (%) by age

In recent years, personal electric mobility devices (PEMDs) have been rapidly entering the road transport system and have become a popular alternative mode for people who were previously using cars, motorcycles, or bicycles, or were walking. In view of this trend, it is important to understand the potential safety risk associated with PEMDs. This project analyzed PEMD-related injuries for a period of 10 years (2006 to 2016) using data obtained from the National Electronic Injury Surveillance System (NEISS) database. The national estimate from sampled hospitals was 13,306 injuries for the study period. Analysis of the data revealed that about 66% of injuries involved males, with a large group of the injuries (58%) occurring for children aged less than 16 years. About two-thirds of the injuries occurred during weekdays, and about 36% occurred in the summer months. The majority of injuries were in the upper body area.

2018 CUTC MEETING

This June, C^{2}M^2 Director Dr. Mashrur "Ronnie" Chowdhury, Program Coordinator Charlotte Ryggs, and Grant Administrator Karen Lantgios traveled to Minneapolis to attend the 2018 Council of University Transportation Centers (CUTC) Summer Meeting. This annual meeting, hosted by the Center for Transportation Studies and the University of Minnesota, gave an opportunity to network with other representatives from University Transportation Centers around the country and to attend three days of meetings, presentations, and tours. This summer's meeting focused on engaging students in transportation research, encouraging the community to cooperate in research projects, and sharing tips and strategies among participants to more efficiently run their UTCs. This meeting also provided an opportunity for our representatives to meet with individuals from the US Department of Transportation and the Transportation Research Board, which provided updates on upcoming initiatives and changes in the UTC reporting process that will be taking place in the coming year. This meeting provided an excellent opportunity for our center's representatives to build relationships with other UTC members and foster future collaborations. We look forward to attending next year's conference in Norman, OK.

CONNECTED VEHICLES WORKSHOP

On June 26, 2018, Dr. Dimitra Michalaka of the Citadel planned and hosted a Connected Vehicles (CVs) Workshop to coincide with the ITE/ASCE summer meeting. It took place at the South Carolina Department of Transportation District 3 building in Greenville, South Carolina. This workshop featured Dr. Mashrur "Ronnie" Chowdhury, who gave an overview of CV research conducted at C^{2}M^2. It also featured Mr. Kris Milster, Director of Government Accounts with Traffic Technology Services, who discussed signal phasing and timing (SPaT); MAP information; cellular-based technology in Audi/VW, BMW, and Kia vehicles; Continental drivetrains; predictive algorithms; and backend technology working principles. Mr. Milster addressed the question: What do car manufacturers need from state and local DOTs? Mr. Peter Ashley, VP of Business Development & Marketing at Applied Information, rounded out the workshop by showcasing the TravelSafely app, which connects road users to one another through smartphones, giving heads-up alerts about approaching hazards. TravelSafely has already been deployed in over 200 cities. This workshop was attended by 29 transportation professionals from throughout South Carolina. Participants were granted professional development hours for attending.

SUMMER TECHNOLOGY DEMONSTRATIONS AND OTHER ACTIVITIES

C²M² was delighted to once again partner with Benedict College's Summer Transportation Institute (STI) to bring high school and middle school students from throughout South Carolina to Clemson for a technology demonstration. During the week of June 18–25, 2018, Dr. Chowdhury of Clemson, Dr. Comert of Benedict College, and Dr. Huynh of USC presented multiple technology demonstrations to students who are interested in the transportation industry. Students visited both Clemson and USC for these demonstrations, and also toured the Inland Port Authority in Greer, SC. Drs. Chowdhury and Comert also collaborated to bring an additional group of students participating in Benedict College's Cybersecurity Summer program to Clemson for a demonstration of the collaborative CAV cybersecurity project they are working on. In addition, this summer C²M² was invited to give technology demonstrations during the two-day Society of Automotive Engineers (SAE) Automated and Connected Vehicle Systems Testing Symposium, which was held June 20-21, 2018 at the Clemson University International Center for Automotive Research (CU-ICAR) in Greenville, South Carolina. C²M² also participated in a Department of Transportation (DOT) Peer Exchange hosted by South Carolina Transportation Technology Transfer Services in August. In addition, South Carolina State University hosted high school students from Michigan who were participating in the Summer Transportation Institute (STI) in conjunction with the Michigan Department of Transportation.

Connected and automated vehicle demonstration at the Society of Automotive Engineers (SAE) Automated and Connected Vehicle Systems Testing Symposium

Benedict College's Summer Transportation Institute (STI) students attending Connected and Automated Vehicle (CAV) Demonstration at Clemson University

Benedict College students participating in the Clemson University Hackathon September 9, 2018

2018 ADVISORY BOARD MEETING

The second meeting of the C²M² Advisory Board took place at the Madren Center in Clemson on Wednesday, October 24, 2018. The purpose of this meeting was twofold. First, the board discussed the center's technology transfer plan, matching funds, and how C²M² can become self-sustaining by generating resources from different activities, such as offering autonomous vehicle workshops/training sessions with a fee for attendees. Second, the Advisory Board members nominated a new chair, Dr. Nadim Aziz. As not all the advisory board members were present at the meeting, the actual election has been delayed to allow all of the board members to let us know if they want to nominate any other candidates.

2018 UTC GRADUTES

In this reporting period, C²M² saw the first of its supported students graduate. Zadid Khan and Mhafuzul Islam, from Clemson University, and Sumanth Byraju, from University of South Carolina, were granted master of science degrees. These students will continue to work with C²M² as they pursue their doctoral degrees. Mizanur Rahman, from Clemson University, became the first of our C²M²-supported students to receive his doctoral degree.

UPCOMING EVENTS

Distinguished Speaker Series

In the coming months, C²M² will continue its Distinguished Speaker Series, sponsoring talks by noteworthy transportation researchers. These presentations will be announced on our social media platforms and made available via webinar.

Transportation Research Board Conference

C²M² researchers and affiliated students will be attending the 2019 Transportation Research Board Annual Meeting in Washington DC, presenting papers on their sponsored research. Based on the C²M²'s research, a total of six research papers will be presented at the 2019 Transportation Research Board Annual Meeting.

See You Soon!

Thanks for following C²M²'s activities! More on how we are striving to advance the field of transportation will appear in our next newsletter. In the meantime, check our website at https://cecas.clemson.edu/C2M2/ for new information.