Program Progress Performance Report
for University Transportation Centers

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Research and Innovative Technology Administration
UTC Program

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Project Title: Technologies for Safe and Efficient Transportation (T-SET)
National University Transportation Center for Safety

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Major Goals and Objectives of the Program

Research, Development, Deployment
The CMU-Penn T-SET UTC focuses on safety. Our research is specifically targeted at improving the safety of automotive drivers and passengers, bicyclists and pedestrians, and the safe usage of trucks and mass transit vehicles.

The thrusts of the T-SET UTC are structured along 5 core areas: In-Vehicle Technologies, Infrastructure Technologies, Human-Vehicle Interactions, Mobility/Data Analytics and Policy.

Metrics:
- Faculty scientific leadership as reflected by the number of publications and citations of faculty work in transportation-related areas;
- The number of staff, faculty and students involved in leadership positions in academic, industry and government transportation organizations;
- New research collaborations in fields related to this work;
- Successful technology deployments and their impact; and
- Patents and start-ups.

Education and Workforce Development
Education and workforce development are important complements of the T-SET research program.

Metrics:
- Number of transportation-related courses,
- Students participating in transportation research projects,
- Advanced degree programs funding T-SET UTC students,
- T-SET UTC-funded graduate students,
- T-SET UTC-funded students who receive degrees,
- Institutional educational partnerships, and
- Participants in workforce and educational programs.

Technology Transfer
The CMU-Penn UTC will fully use the resources and the experience of these university centers to promote enterprises arising from its research program. Faculty who already created startups in the past, serve as mentors to colleagues interested in this activity.

Metrics:
- Simple adoption of the innovation by a transportation operator, company or public, to more formalized outcomes such as licensing, patents, commercialization, and spin-off companies.
- Quantify numbers of meetings, attendance, publications, and social media and website activity.

Collaboration
Collaboration is the heart of the entire T-SET program. CMU and Penn seek to ensure our research and development program leads to deployment of technologies in the transportation systems serving our communities and state, providing pilot applications for global use. The CMU-Penn team will collaborate with related centers on the two campuses, state and local public partners, non-profit community partners and industry partners.

- Number and diversity of members of both the T-SET Consortium and Advisory Council, and by the
- Number and impact of deployments achieved through collaboration
Accomplishments Under Major Goals
See Appendix A for specific research project accomplishments.

Research, Development and Deployment
T-SET’s major accomplishment for the period of reporting was hosting the 2\textsuperscript{nd} Annual UTC Safety Summit. There were 65 participants including 14 UTCs and national representatives from government, industry and community groups. USDOT Assistant Secretary, Greg Winfree, was the lunch keynote speaker.

Other Research, Development and Deployment activities include:
- Attended NRC Pathways to Sustainability Committee Meeting
- Attended Volpe-Cylab Meeting on Vehicle Cybersecurity
- Attended TRB Special Projects and Policy Committee
- Attended NRC FHWA R&D Oversight
- Attended PA Turnpike Project Scoping Meeting for Mobility Analytics and Accident Reconstruction
- Hosted Postmaster General Visit to CMU to discuss Road Surface Monitoring and Automated Vehicles
- Research Presentation to PennDOT District 11
- University of Pittsburgh Transportation Forum
- Meeting with CEO of the Pittsburgh Parking Authority for Data Sharing
- Met with Bike Pittsburgh to discuss bicycle detection
  met with Matt Baumann, PHD at Pitt to discuss bicycle detection
- Met with the Airport to discuss future research opportunities
- Brought Researchers to Pitt Ohio facility to discuss research opportunities
- Met with Butler county to discuss freight prioritization
- Meeting with Mapillary to discuss partnership

Education and Workforce Development
During this reporting period, we established a new Women in Transportation Summer Scholars Fellowship for undergraduates in partnership with the Robotics Institute, became active members in Women’s Transportation Seminar Transportation U activities, focused efforts on expanding the programming of the Transportation Club, and partnered with PennDOT on workforce development.

Education and workforce development activities include:
- Meeting in State College PA of the Pennsylvania Consortium of Transportation Universities
- Hosted a student tour at Google offices in Pittsburgh
- Guest Lecture at Master of Urban Design Course
- Meeting with Student Starting AASHE Student Chapter r
- Heinz College Capstone Advisory Committee for Autonomous Shuttle
- Heinz College Capstone Advisory Committee for Airport disabled travelers
- Hosted Vinn White Presentation at the Heinz College
- Hosted 4 T-SET faculty meetings
  Hosted first event in series of Tranportation Tech Nights, Bike Hack Night: Speed Monitoring
Meeting with Aimee Jefferson regarding Transportation Technology Transfer & Collaboration
UTC Consortium Meeting was held on November 12, 2015 at Carnegie Mellon University. The consortium meeting featured a research and deployment fair, where community, government and other partners could meet our researchers and learn more about their research.

Other Technology Transfer and Collaboration Activities include:
- Faculty Seminar Presentation: Kari Watkins, visiting faculty from Georgia Tech presented work on OneBusWay, an open source platform for real time transit information. For those who were not able to attend, the presentation was live streamed and uploaded to our Learning Channel.
- Seminar Presentation. Corey Harper presented on Estimating Safety and Costs and Changes in Vehicle Miles Traveled from Vehicle Automation. For those who were not able to attend, the presentation was live streamed and uploaded to our Learning Channel.
- Faculty Seminar Presentation: Greg Barlow presented on Surtrac Updates and What’s Next for the Adaptive Traffic Signal Systems. For those who were not able to attend, the presentation was live streamed and uploaded to our Learning Channel.
- Deployment Seminar Presentation: Lee Haller from Pittsburgh DPW joined CMU faculty member Steve Smith to present on snow plow routing in the City of Pittsburgh.
- Meeting with CIE regarding Entrepreneur In Residence collaboration
- Attended the Regional Data Center Kick-off
- Attended Northwestern - Trans. Institute Review
- Attended ASCE Editors Workshop
- Attended Pittsburgh Smart City Planning workshop
- Traveled to Singapore to hold meetings with Singapore Management University
- Traveled to Adelaide to hold meeting with Carnegie Mellon Adelaide Australia Campus
- Facilitated Pittsburgh Smart City Challenge Partner Charrette
- Attended UTC/CUTC Winter Meeting
- Hosted Leadership Pittsburgh Class Visit to CMU
- Hosted Smart City Council Jesse Bearst Visit to CMU
- Hosted SAE Visit to CMU
- Hosted Verizon Visit to CMU
- Attended Meeting with Coalition to Support Inner City Rail
- Attended Meeting with Director of the Pittsburgh SBA Office
- Meeting with CEO of the Southwestern PA Commission to discuss Mobility Analytics
- Meeting with the Allegheny Conference on Community Development to discuss Mobility Analytics
- Speak at the International Bridge Tunnel and Turnpike Association Transportation Policy and Finance Summit
- Hosted Mayor Peduto Smart City Challenge Press Event at CMU
- Attended ITS World Congress in Bordeaux, France
- Sat on Panel at the American Architectural Foundaiton Forum on Automated Vehicles
- Exhibited in the ITS America Capitol Hill Technology Showcase
- Keynote speaker at Dinner Meeting of the SWPA Chapter of ASHE
- Attended TRB UTC Spotlight Conference on Connected and Autonomous Vehicles
Hosted PNC visit to CMU
Attended ITSA Board Meeting
Presented at Penn State Transportation Safety and Engineering Conference
Sponsored Greater Pittsburgh Chamber of Commerce Public Officials Reception
Met with French autonomous vehicle company, Navya
Attended Transit Geeks
Attended SAFE Fifth Forbes Now Committee meeting
Met with TomTom to discuss partnership with City of Pittsburgh

Met with SPC regarding Road Safety Audits
Met with McKees Rocks Community Group regarding Freight Prioritization
Participated in Platform Pittsburgh meeting hosted by City of Pittsburgh
Presented at AV Symposium Workshop at TRB
Attended SXSW for Smart City Challenge events
Participated in Smart City webinar for NOFO#2

Diversity
T-SET continues to push initiatives that support women in the intelligent transportation domain including:
- Supporting the Women in Transportation Fellow to attend TRB Annual Meeting
- Member of the board of Pittsburgh Chapter of the Women’s Transportation Seminar
- Member of the Northeast Regional Council of the Women’s Transportation Seminar
- Participated in WTS Scholarship Committee
- Sat on Women’s Forum Panel with Sec. Richards
- Held a meeting of the Women’s Graduates in Transportation Group
- Worked with WTS International on the Transportation YOU steering, leading the development of the challenge book for high school girls at the Transportation U event to be held in DC, summer 2016.

Products
General Program Products
- UTC website www.utc.ices.cmu.edu
- 5749 blog posts
- Consistent weekly distribution of T-SET email newsletter, 1,550 subscribers
- Continue to use a webinar-based system of linking CMU and UPenn faculty and students for our bi-monthly T-SET meetings. Now a faculty member interactively presents their research at the beginning of each meeting.
- Promotion of various CMU and Penn research news articles in the T-SET blog and newsletter

T-SET In the MEDIA
March 31, 2016 Pittsburgh Mayor Peduto in San Diego to pursue Smart City Challenge grant

March 25, 2016 CMU Study: autonomous vehicles could improve MPG 10% in EPA tests

March 24, 2016 CMU Featured in Sec. Foxx's Blog "Different Pathways Lead To Transportation Careers"

March 24, 2016 VIDEO: CMU "Eyes on the Road" video highlights Christoph Mertz's Road Surface Monitoring Work

March 23, 2016 Uber Wants to Be Hacked

March 18, 2016 NYT: Autonomous Cars Aren't Perfect, but How Safe Must They Be?

March 17, 2016 CONGRATS! Pittsburgh one the Smart City Challenge Finalists.

March 17, 2016 VIDEO: CMU's Raj Rajkumar on Smart Cities

March 17, 2016 Driverless Cars Must Have Steering Wheels, Brake Pedals, Feds Say

March 9, 2016 After Uber exodus, Carnegie Mellon lands $11M in contracts

March 9, 2016 Federal policy reverses benefits of alternative fuel vehicles

March 4, 2016 Self-Driving Cars Are Coming, But They’re Not Ready For Pittsburgh Yet

February 20, 2016, Uber considers building test track in Hazelwood

February 22, 2016 How TomTom is plotting a route into US driverless car industry

February 11, 2016 - INFOGRAPHIC: The Virtuous Cycle Between Driverless Cars, Electric Vehicles and Car-Sharing Services

February 11, 2016 - The Case for Making Self-Driving Cars Think Like Humans

February 11, 2016 - CMU Heinz College seeking Women in Transportation Fellow for Fall 2016

February 3, 2016 - CMU advances in high-speed ground transit competition

February 2, 2016 How Technology Is Helping the Blind Navigate the Physical World

January 28, 2016 - What will cheap gas do to electric cars?

January 28, 2016 - Uber Is Making Sure Those Bad Driver Ratings Are Correct

January 26, 2016 - Uber monitoring drivers in US in attempt to flag dangerous driving

January 26, 2016 - What will cheap gas do to electric cars?

January 26, 2016 - Uber monitoring drivers in US in attempt to flag dangerous driving

January 21, 2016 - Watch a Drone Helicopter Release a Driverless Ground Vehicle

January 21, 2016 - At Carnegie Mellon, a Futuristic Vision for Hyperloop, and the Finances to Match

January 20, 2016 - Pa. Turnpike, Waze app team to map out best routes

January 20, 2016 - NYT: For Now, Self-Driving Cars Still Need Humans

January 15, 2016 - The firms who will beat Google to get us into self-driving cars

January 12, 2016 - Apple registers car-related web addresses as vehicle rumours gather speed

December 31, 2015 - Newsmaker: Ramayya Krishnan

December 24, 2015 - Pittsburgh shines as beacon of opportunity for tech firms

December 24, 2015 - Driverless Cars are Too Cautious for Chaotic Human Drivers

December 24, 2015 - Pittsburgh on the road to ‘inclusive innovation’
Appendix A – Research Projects Accomplishments, Products and Participants
**Mobility Data Analytics Center, PI:** Sean Qian, CMU, **Students:** Xidong Pi, Yiming Gu  
**Deployment Partner(s):** Port Authority of Allegheny County, Department of Public Works of the City of Pittsburgh, Healthy Ride Pittsburgh (bikeshare)  
**Journal Publication(s):**  
**Other publications, conference papers and presentations:**  
2) Sean Qian, (2016) Dynamic network analysis for the Philadelphia Metro Area, presented in ITS-PA annual meeting  
**Website:** Mac.heinz.cmu.edu/traffic  
**Impact:** In the past two years, we have started building the data engine and a prototype web application to demonstrate the feasibility of Mobility Data Analytics Center. We started from the Pittsburgh region where we have close partnerships with many local entities, and have successfully applied our data analytics tools in several case studies. The main accomplishments are summarized as follows,  
1. We have analyzed large-scale 911 incidents data in Pittsburgh Region, and developed an online tool to visualize and forecast crash types, frequencies and severity for each road segment. The tool has been tested.  
2. We have also collected and fully analyzed the following bike related data sets:  
   a) Protected bike lanes, and the traffic flow volumes and travel speeds on those road segments  
   b) Ride easiness. We use high-resolution elevation data to compute the slope of each road segment for each direction.  
3) Bike crash risks for each road link.  
4) Traffic volumes and traffic speed for each road link.  
We have developed formula for computing bike scores for all road segments that take into account all those factors. We are currently develop the web application for disseminating this information.  
**Impact on Technology Transfer:** The web application for bike score has great potential to be commercialized and serve the mobility sustainability.  

**Sharing Costs of Vehicle-to-Infrastructure Deployment for Safety, PI:** Jon Peha,  
**CMU Students:** Alexandre Ligo  
**Deployment Partner(s):** The vehicular network trial we use in our research is operating in the City of Porto. The University of Porto has shared data with us. The Ph.D. student working on this project has spent time in Porto, and the University of Porto has provided him office space when he is there.
Acknowledged federal support.


Other dissemination activities: Made a presentation to leadership at the U.S. Federal Communications Commission (FCC) on this research, and its implications for FCC regulations on spectrum for Intelligent Transportation Systems.
Website: https://users.ece.cmu.edu/~peha/vehicular.html

Impact: This program has contributed to transportation research by showing that DSRC-based connected vehicle mesh networks can be cost-effective as dual-use technology, i.e. they can support both safety applications and provide Internet access in a way that is more cost-effective than cellular networks. In particular, our results show that these vehicular networks will be more cost-effective than cellular networks just a few years after deployment in densely populated cities like Chicago, Boston, New York and San Francisco. In the years that follow, they will become cost-effective in regions with lower and lower population densities. This is an extremely important result for those who care about bringing low-cost mobile Internet access to our cities. These results also support the hypothesis that the sharing of infrastructure between government entities that wish to enhance vehicular safety and Internet service providers could be cost effective, and could thereby save federal, state and location transportation departments a great deal of money. We hope to test that hypothesis further in the coming year.

This program has contributed to transportation education by supporting one Ph.D. student, and by bringing educational content on connected vehicles into Carnegie Mellon University courses on wireless networks, making that content available to both undergraduate and graduate students.

Impact in other disciplines: Because this research is on connected vehicles, it has impact on both transportation and telecommunications. The impact on telecommunications is both technical and economic. First, as described above, our results show that connected vehicles offer a new way to provide mobile Internet access, and that this approach will soon be more cost-effective than today’s approach in urban areas. Second, our results show that connected vehicles scale well, which has been an open research question. In particular, even when the number of DSRC-equipped vehicles per square mile and the data rate per vehicle are greatly increase, the mechanisms that deal with congestion and interference are sufficiently effective that throughput remains stable.

Impact on Technology Transfer: We have presented results to the U.S. Federal Communications Commission (FCC), and offered advice to them on connected vehicles. The FCC has important decisions to make regarding spectrum used for
Intelligent Transportation Services, and technical standards for devices that operate in this spectrum band.

**Multimodal Distraction Detection, PI:** Maxine Eskenazi, CMU, **Co-PI:** LP Morency, **Students:** Yulun Du (formerly Shrimai Prabhumoye)

**Other publications, conference papers and presentations:** UTC Summit Showcase, March 30, 2016 Washington DC

**Other dissemination activities:** The database that we are in the process of creating is being structured in a way that will allow for easy dissemination to anyone who requests it. We have also crafted our consent form so that the data can be used by others and can be annotated.

**Website:** [http://utc.ices.cmu.edu/utc/projectitem.asp?ID=192](http://utc.ices.cmu.edu/utc/projectitem.asp?ID=192)

**Technologies / Techniques:** We are in the process of creating a database of subjects using a driving simulator and being distracted by emails, texts and phone calls while doing so. We will have 50 subjects by the end of 2016. There is a back-facing camera that captures both the subject, their head movements, gaze, etc and the audio of the session.

We will use this data to have a fuller picture of the conditions that cause distraction and of different degrees of distraction. We will use machine learning on this dataset to automatically determine when a driver was distracted.

**Other Products associated:** The abovementioned dataset.

**Please explain:** The dataset, when finished, will be advertised at major conferences and through mailing lists to colleagues who can request a copy for their own research.

**Impact:** This dataset should dramatically change the way we look at distraction. So far, researchers have taken it to be very straightforward to detect distraction - whenever there is a change in some constant user behavior, there is distraction. This leads to many false positives and to the user abandoning any warning system based on this approach. We depart from that view by standing on solid psychology research that shows that distraction is a more complex event, changing from one individual to another and changing according to the type of cognitive load and task that the individual is confronting.

**Impact in other disciplines:** Results of our work (when implemted and tested) should reinforce the theories put forward in psychology.

**Non-intrusive Driver Fatigue and Stress Monitoring Using Ambient Vibration Sensing, PI:** Hae Young Noh, CMU, **Co-PI:** Pei Zhang, **Students:** Susu Xu, Frank Mokaya, Amelie Bonde

**Deployment Partner(s):** Renault Innovation Silicon Valley, 1215 Bordeaux Dr, Sunnyvale, CA 94089

Together with Renault, we evaluated our system in a realistic situation during driving scenarios. We used their driving simulation facility to test driving stress, noise model and noise separation algorithms efficiency in a controlled and safe environment. In addition, we utilized the research Nissan Leaf vehicle at the lab to test our algorithm with the subject in the passenger seat on isolated roads in the NASA research center where CMU SV campus is located.

Other dissemination activities: 1. We presented our work at Intel, February 2016. 2. We gave a seminar on this project at Lehigh University, Bethlehem, PA, April 2016. 3. We presented our work at Microsoft Research, May 2016. 4. We presented our work at IWCPS workshop, August 2016.

Website: https://www.cmu.edu/cee/people/faculty/noh.html, https://www.cmu.edu/silicon-valley/faculty-staff/zhang-pei.html

Technologies / Techniques: We have been developing a driver fatigue and stress monitoring system using embedded accelerometers in car seats. These sensors can sense physiological states of the driver, such as movement, heart rate, and breathing, and then infer high level driver status, such as attention level and stress. Our algorithm combines analytical human model with data-driven approaches to reduce modeling uncertainties and noise in the signal. The developed technologies are and will be shared through publications and PIs’ research lab website.

Other Products associated: We created a demo based on this project. A car seat cushion with embedded accelerometers measure and display heartbeat signals from a person sitting on it. This demo has been presented during our other dissemination activities described above.

Impact: By monitoring the fatigue and stress level of the driver through the physiological variables, we enable the autonomous cars to understand the capability of the driver to take the control back in dangerous and/or unexpected situations. This will further improve the safety of the autonomous vehicles in dangerous situations. The PIs also plan to use the developed demo for outreach and education activities at CMU.

Impact in other disciplines: Our research has impacts in many other disciplines. First, the development of our sensing system can be applied to other fields for non-intrusive indirect monitoring through vibration, such as wearable suits for muscle monitoring in sports activities, smart furniture to sense human activities, etc. Second, the inference algorithm to extract driver’s status from noisy vibration data can be applied to the areas, which requires signal decomposition to separate various components in the vibration measurements, such as vehicle-infrastructure interaction, manufacturing, infrastructure monitoring, etc. Third, we can understand the driver behaviors across different scenarios, which can be incorporated into car interface design and traffic management.


Other Collaborators: • More than 9 research fellows at CMU, HCI Institute, Ubicomp Lab – Two postdocs (Dr. Jaemin Chun and Dr. Sungyoung Cho), three visiting scholars (Jung Wook Park, Prof. Kyung-Joong Kim, and Dr. KyungTaek Lee), and more than four undergraduate or graduate students as volunteer or paid research assistants, or students for their independent studies (Nana Choi, Raghavendra Kandala, Helen Kim, Daniel Lee, etc.)
• More than 3 collaborators from the current or future non-CMU deployment partners – Cindy Cohen (Cindy Cohen School of Driving, LLC), Dr. Hyoseok Yoon (KETI, Contents
Convergence Research Center, Republic of Korea), Prof. Ian Oakley (UNIST, Interaction Lab, Republic of Korea), Seo-ho Choi (Hyundai Motor Group – Human Factors and Device Research Team in the R&D division, Republic of Korea)

**Deployment Partner(s):** CMU, Human-Computer Interaction Institute (HCII), Ubiquitous Computing Lab; Provided the KETI matching/leverage fund; Provided an in-kind support (e.g., sensor devices used in data collection) and personnel support (e.g., post-doc researchers, undergraduate research assistants; Performed collaborative research on 1) visual analytic tools for time-series sensor data during naturalistic driving, 2) integrated driver aware systems for field driving experiments, and 3) experience sampling methods to evaluate the usability of wearable devices and the perceived values of in-car information delivered to drivers.

**Journal Publication(s):**


**Other publications, conference papers and presentations:**


Other dissemination activities: Invited talks and presentations
• Samsung S/W center, Artificial Intelligence Lab, Seoul, South Korea (Aug 11, 2016)
  o Topic – Improving the Quality of Driver Experience in Ubiquitous Human-Computer Interaction Situations in Cars
• Gwangju Institute of Science and Technology (GIST), Institute of Integrated Technology, Gwangju, South Korea (Aug 9, 2016)
  o Topic – Improving User Experience in Ubiquitous Human-Computer Interaction Situations (Enabling Computers to Know the When, How, and What of Interaction with Humans)
• Delphi Automotive PLC (CMU visitors, Jun 28, 2016)
  o Topic – Real-time Detection of Driver Interruptibility
• Korea Electronics Technology Institute (KETI), Contents Convergence Research Center, Seoul, South Korea (Apr 28, 2016)
  o Topic - Machine Learning Applications in Human-Computer Interaction
• Korea Electronics Technology Institute (KETI), IoT Platform Research Center (Apr 20, 2016)
  o Topic - Sensors Know When to, How to, and What to Interact with Human
• Hyundai Motor Company, Human Factors and Devices Research Group, Uiuwang, South Korea (Apr 19, 2016)
  o Topic – Driver Experience in Ubiquitous HCI in Cars
• The University of Alabama At Birmingham (UAB), Dept. of Computer and Information Sciences, Birmingham, Alabama, USA (Feb 17, 2016)
  o Topic – Improving User Experience in Ubiquitous Human-Computer Interaction Situations (Sensor-based approaches to better understanding human capability in attention and cognition)


Technologies / Techniques: 1. Human-in-the-loop cyber-physical systems technology to make computer-assisted driving more acceptable and dependable in futuristic cars
  2. Visual analytics technology to create machine learning applications for multi-modal behaviors revealed in big sensor data streams.
  3. Sensory augmentation technology to improve HCI experience in context-aware applications in vehicles

Invention / Patent applications / Licenses:

Other Products associated:
• Video/Audio
• Physical collections
• Software

Please explain:
• Video and audio of the front road traffic and drivers’ in-car activities.
• Study participants’ responses for a set of survey questionnaires.
• Synchronized multidimensional sensor data streams collected during naturalistic driving.
• Visual analytic tools whose features are integrated into a machine-learning pipeline

**Impact:** Presents an enabling in-vehicle technology to make computer-assisted driving in futuristic cars more acceptable and dependable, based on sensor-based assessment of interaction quality between driver interruptibility and proactive HCI demands in cars

**Impact in other disciplines:** 1) Adaptive cyber-learning (e.g., supporting student learning by adapting computer-based tutoring to individual learning phase and real-time capabilities with a sensor support), 2) human-robot interaction (e.g., supporting social interaction between people and robots by enabling robots to determine how and when to interact with people), and 3) sensory augmentation domains (e.g., supporting a safe equilibrium between the benefit of provided intervention – i.e., value-to-get – and mental demand associated with its attentional interference – i.e., cost-to-spend – in smart and connected environment)

**Impact on Technology Transfer:** • Derived a joint research item with an industry, Hyundai Motor Company (HMC, one of non-CMU deployment partner Human Factors and Devices Research Team in the R&D Division) on sensor-based assessment of contextual factors to understand the interaction between driver interruptibility and dialog-based HCI demands in cars (Note: for now, the actual contract between HMC and CMU has been ceased in the middle of contract process since both CMU and HMC have realized that HMC’s demand was closer to work-for-hire type project, rather than an academic research, and then both parties decided to postpone related discussion up to the next year.

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**Do Vehicle Safety Inspection Programs Result In Younger, Safer Fleets Or Do Younger, Safer Fleets Lead To Significantly Safer Vehicles?: The national effects and underlying benefits of the vehicle safety inspection program on the vehicle fleet or vice versa, PI: H. Scott Matthews, CMU, Co-PI: Paul Fischbeck and Chris Hendrickson, Students: Dana Peck, Michelle Liu

**Deployment Partner(s):** CompuSpections, LLC, 1177 Pittsburgh Rd, Valenica, PA 16059. In-kind support: provided significant amount of data related to vehicle inspection characteristics and other details. They also provided many hours of in-kind technical support and background information related to transportation safety issues.

Collaborative research and personnel exchange - we had various meetings at CMU and their headquarters, used their office space when needed to manage data transfers, etc.

**Journal Publication(s):** Manuscript was submitted (not yet published): VEHICLE SAFETY INSPECTIONS AFFECT ON URBAN/RURAL FATALITY RATES, Peck, Fischbeck, Hendrickson, and Matthews, Accident Analysis and Prevention, 2016.

**Other publications, conference papers and presentations:** During this time period, time was spent on preparing a poster presentation (by Dana Peck) for the annual TRB conference in early January in DC.

**Other dissemination activities:** We held a meeting in November 2015 at PennDOT to discuss the results of this research (as well as other related work).

**Website:** gdi.ce.cmu.edu

**Technologies / Techniques:** We developed methods to assess fatality rates from reported data in conjunction with other sources.
Please explain: We had to end the project early (March 2016) when the student leading the research accepted a post-doctoral fellow position at US DOT, and since there were no other students able to continue the proposed work.

Impact: While the project had a premature ending due to personnel constraints, in addition to modifying regression analyses for modeling motor vehicle fatalities across the U.S. and comparing States with more stringent safety inspection programs to those with less stringent programs to conclude whether having the annual vehicle safety inspection program is associated with fewer vehicle fatalities.

We also reported on another research topic on vehicle travel trends was in progress. This research used PA emission inspection data which contained odometer readings for vehicles at the time of the annual inspection (along with inspection dates, registration zip code location, and vehicle characteristics) and allows for travel trends to be analyzed at the zip code level. In addition to vehicle travel trends, this data also allows for household travel trends and household vehicle preference by using a household identifier.

The results of this work are useful in the transportation domain because they perform detailed comparisons of publicly available data sources to generate fatality rates useful for intrastate comparisons against the existence of safety inspection programs.

Impact in other disciplines: There are potential impacts to the field of data science as well as in vehicle design.

Stereoscopic Programmable Automotive Headlights for Improved Safety on the Road, PI: Srinivasa Narasimhan, Robert Tamburo, CMU, Students: Srihari Sankar

Other Collaborators: James Hoe, ECE professor, CMU has been involved with the project for some time to lend his expertise. Marie Nguyen, ECE PhD student, is working on FPGA development as part of her thesis work. Anthony Rowe, ECE, professor, CMU has been involved with the project for some time to lend his expertise.

Deployment Partner(s): Financial support:
NSF grant awarded to supplement funding towards the project. NSF (CNS-1446601).

CPS: Synergy: TTP Option: Anytime Visual Scene Understanding for Heterogeneous and Distributed Cyber-Physical Systems.

Closely working with the National Robotics Engineering Center (NREC) to further develop project. They assist with facilities, staff, and equipment.

We are currently in talks with General Motors, Ford, and Honda for partnership (financial support, resource support, and/or domain support)


Website: http://www.cs.cmu.edu/~ILIM/projects/IL/smartHeadlight/

Technologies / Techniques: We have developed headlights that can perform 3D reconstruction while driving. Distance estimations are used to improve classification algorithms. Our two programmable adaptive automotive headlights can also react to detected objects based on their measured shape. In order to accomplish the above, custom hardware, software, and algorithms were developed.
Other Products associated: FPGA accelerated algorithm for stereo matching and computing disparity maps. Architecture for transmitting and receiving data between headlight prototypes. A unique data set will be acquired in the coming months-- images from two cameras while driving on various roads in different weather conditions.

Impact: Our technology has numerous benefits towards improving safety on the road. As a programmable, stereoscopic headlight, we have available a platform available for developing never-before-seen safety features for automotive headlights. Developments are underway to create an easy to use API for developing algorithms for our headlight system. We plan to engage with students through workshops and courses to teach them the API, and possibly, hold contests for best features developed. We have engaged with multiple entities in industry to move towards partnerships and commercialization in order to see our safety device on the road as soon as possible.

Impact in other disciplines: We have demonstrated utility of our methods in the field of computational photography. We have also expect our work to benefit the area of cyberphysical systems.

Optimizing Snow Plowing Operations in Urban Road Networks, PI: Stephen F. Smith, CMU, Co-PI: Joris Kinable, Students: Suryansh Saxena

Other Collaborators: Prof. Willem van Hoeve, Assoc. Prof. of Business, has participated in the design of the snow plow routing algorithms we have developed

Deployment Partner(s): Organization: City of Pittsburgh, Public Works Department Location: City-County Building, Grant Street, Pittsburgh PA

Partners Contribution: In-Kind Support

Facilities: Knowledge acquisition visits at both PWD office and Division 3 Snow Plow facilities

Collaborative research: PWD staff have shared expertise and data from their current "Route Smart" snow plow routing software; Plowing personnel have provided knowledge on their operations and snow plow planning constraints.

Personnel Exchanges: Project not yet at the stage where this step is useful.


Website: under construction

Technologies / Techniques: Thus far, the project has developed the following technologies:

(1) A prototype plowing route planner that generates snow plow routes that considers such objective criteria as minimizing completion or deadheading times, subject to roadway characteristics (e.g., number of lanes, directionality, segment distances) and vehicle constraints (fuel, salt capacity, travel speed). The planner accepts map data for
a given plowing area from Open Street Maps and returns a set of feasible vehicle routes for clearing it. The planner generates routes incrementally, which makes it ideally suitable for also reactively revising a set of routes in response to an unexpected problem (e.g., an abandoned vehicle blocking a road segment).

(2) A mobile app that runs on a tablet that is intended to reside in each snow plow vehicle and provide the vehicle with turn-by-turn instructions. The mobile app receives as input a generated snow plowing route, and converts this route into turn-by-turn instructions as the route is executed.

**Impact:** This project has made fundamental contributions to the snow plow routing research, contributing new search techniques for generating routes under realistic snow plowing constraints. We also expect the project to positively impact snow plowing operations in Pittsburgh. Our goal is to transition the capabilities we are developing into operations. Just the ability to communicate turn-by-turn instructions to drivers, a capability that we plan to pilot test this winter, will provide a significant advance over the current practice of reading routes printed on paper in the vehicles and reporting status by hand on these same sheets. The ability to better optimize routes, which we intend to deliver in the longer term, will result in better service and more efficient use of snow plowing resources.

**Impact in other disciplines:** There are a range of municipal transportation services for which the technologies being developed could be applicable including trash pickup, street cleaning and local freight delivery.

**Impact on Technology Transfer:** As indicated above, we expect to transition both in-vehicle technology for generating turn-by-turn instructions to drivers, and backend route generation and revision capabilities for managing overall operations.

**Route 51 Corridor Transformation: Phase II, PI:** Donald K. Carter, CMU, **Students:** Yuan Zi, Marantha Dawkins

**Other Collaborators:** - Economic Development South (EDS): in kind contributions to organize and outreach activities
- Deliberative Democracy Program (Dietrich College): to conduct outreach activities

**Deployment Partner(s):** - Heinz Endowments, PennDOT,

**Other dissemination activities:** - The Final Research Study Report or Phase II was submitted to PennDOT for dissemination within the agency.
- Copies will also be distributed to SPC, the nine communities along the Route 51 corridor, PWSA, and ALCOSAN

**Website:** http://www.cmu.edu/rci/

**Technologies / Techniques:** - the SURTRAC micro-traffic simulation model of the Robotics Institute was used in Phase I and Phase II of the research study
- The Deliberative Democracy technique of community engagement was used in Phase I and Phase II of the research study
- GIS technology was used extensively in study, including land use, environmental systems, transportation systems, and economic development scenarios.

**Impact:** **KEY TAKEAWAYS**
1. Transportation Corridors are a new category of roadway classification, not just a new type of roadway.
2. Multimodal design will require changes in standards of design speed, level of service, and traffic calming.
3. Climate Change will alter how corridors will be designed in the future.
4. Federal and Pennsylvania transportation policies and standards are not fully reconciled with multimodal corridor planning.

**Impact on Technology Transfer:** The SURTRAC technology has been patented and spun off as a start up company

**Unsafe Transit Connections, PI:** Aaron Steinfeld, CMU, **Co-PI:** Anthony Tomasic, John Zimmerman, **Students:** Sunny Zheng (undergrad)

**Other Collaborators:** Elizabeth Traut, a post doc in the Robotics Institute, has been partially funded under this project.

**Deployment Partner(s):** Tiramisu Transit LLC, Port Authority of Allegheny County

**Other publications, conference papers and presentations:** 1. "Identifying Commonly Used and Potentially Unsafe Transit Connections With Crowdsourcing" has been accepted for presentation at TRB 2017. This will form the basis for a journal article under preparation.
2. "Tiramisu: A Large-Scale Participatory Public Transit Information System" poster at the 2016 Japan-America Frontiers of Engineering Symposium (JAFOE), National Academy of Engineering (NAE), one of 60 invited engineers.

**Other dissemination activities:** Work from this project, and Tiramisu as a whole, is regularly discussed with reporters, stakeholders, and other interested parties.

**Website:** [http://utc.ices.cmu.edu/utc/projectitem.asp?ID=203](http://utc.ices.cmu.edu/utc/projectitem.asp?ID=203)

**Technologies / Techniques:** Methods for extracting transit connections from smartphone based participatory sensing systems have been developed. The algorithm for this process will be detailed in an upcoming journal article.

**Impact:** We have created new methods for identifying transit connections from smartphone based participatory sensing systems. These methods include generation of new metrics on connection safety and efficiency, including techniques for registering connections with external data (e.g., crime, weather, etc). These methods and metrics have the potential for use by transportation engineers in other regions.

**Impact in other disciplines:** When further along in our work, we will provide new knowledge on where unsafe and inefficient transit connections are occurring in the Pittsburgh region. These findings will have value to transit and infrastructure planners.

**Supporting Bicycle Rider Safety, PI:** Aaron Steinfeld, CMU, **Students:** Sarah Amick

**Other Collaborators:** An RERC-APT staff programmer will assist with aspects of this work in the Fall of 2016.

**Deployment Partner(s):** BikePGH

**Other dissemination activities:** Material from this project is discussed with relevant stakeholders.

**Technologies / Techniques:** Not applicable - this project focuses on gathering stakeholder input and assessing available technologies.

**Please explain:** The team has collected survey responses from over 800 bicyclists in the local region. We are in the process of cleaning and reviewing this data.
Impact: Results from the survey and software review will help inform associated technology development efforts at Carnegie Mellon.

Impact in other disciplines: Some of the survey findings are likely to be relevant to transportation and infrastructure planners within the local region. Some generalizable information might be useful to other regions.

Impact on Technology Transfer: Findings from the survey and software scan may lead to functional specifications for future bicycle safety systems.

Infrastructure Monitoring from an In-Service Light Rail Vehicle, PI: Jacobo Bielak, CMU, Co-PI: Hae Young Noh (CEE), Jelena Kovačević (ECE), Students: George Lederman, Siheng Chen

Other Collaborators: Jim Garrett (CEE), Piervincenzo Rizzo (Pitt)

Deployment Partner(s): Port Authority of Allegheny County: Facilities, In-kind support
We have deployed sensors on their light rail vehicles, which they installed themselves. The Port Authority allows us to use their facilities and has collaborated closely throughout the project.


Other publications, conference papers and presentations: Lederman presented a talk on April 1st at “Forge: New Urban Frontiers,” the 2016 AIAS Northeast Quad Conference held at the Ace Hotel in Pittsburgh, PA. The conference was for architects to learn about technologies relevant to urban planning.

Technologies / Techniques: We have developed a technology to monitor the condition of tracks from in-service train cars. This knowledge is being shared both through publications and with our patent filing.

Invention / Patent applications / Licenses: Filed patent application. Have met with prospective licensees.

Other Products associated: We have collected a large database of train data ~10TB.
**Please explain:** This database has information from 1 train over a 3 year period and a second train over a 1 year period.

**Impact:** Over the course of the year, we have achieved the main goal of this research project: to explore new methods to monitor tracks from operational trains. The impact of this work can be seen in the three main papers from this research and the patent which we filed based on our work. Funds from the UTC allowed us to collect large amounts of data from operational trains, which exceeded previous data-collection efforts in the literature. The quality and quantity of this data allowed us to test and develop new data processing tools. These tools, in turn, provide an alternative, and perhaps more economical way to monitor infrastructure.

This year we developed two new methods: a new sparse approach for analyzing data collected from trains, and a new data fusion approach for combining data from multiple trains. The first method provides a new way to analyze accelerations recorded on a train by decomposing the signal into 1) the properties of the train and 2) the profile of the track. The second method could be important for monitoring tracks from crowd-sourced data. Rather than using data from a single high-quality sensor on a train, we can now combine data from many low-quality sensors, such as sensors which may already exist on the vehicle. These two techniques will help make track monitoring from in-service trains more practical.

This type of sensing, signal processing and data analysis could facilitate safer trains and more cost-efficient maintenance in the future. Moreover, the proposed approach is quite general and could be extended to other parts of the infrastructure, including bridges.

**Impact in other disciplines:** We have worked on incorporating new signal processing techniques into our work (like Sparse Representation) that we are publishing in civil/mechanical engineering forums, which may further encourage collaboration between civil engineering and signal processing.

**Impact on Technology Transfer:** We have filed a patent and are working to license the technology.

*Enhanced pedestrian and vehicle detection using surround-view camera systems,* **PI:** Vijayakumar Bhagavatula, CMU, **Co-PI:** Nothing to report, **Students:** Zhiding Yu

**Deployment Partner(s):** General Motors (GM) has been working with us in this research effort. GM has enabled the acquisition of a surround-view camera which was used to collect the videos used for developing computer vision algorithms and evaluating them.

**Technologies / Techniques:** Computer vision algorithms for detection of road features such as road shoulders, concrete barriers, lane markers and guard rail.

**Other Products associated:** Software and video data base

**Please explain:** We have setup a surround-view camera system on a vehicle and collected videos as the vehicle is being driven on highway. These videos contain relevant highway features such as road shoulders, guardrails, lane markers, concrete barriers and soft shoulders that should be detected for autonomous driving. They also reflect challenging conditions such as strong shadows, image saturation because of bright light and small objects that are at a far distance. We have labeled relevant
regions in many these videos to indicate the locations of these road features in these videos.  

**Impact:** By using synchronized videos of surroundings on all four sides (i.e., front, right-side, rear and left-side) of a vehicle provided by the surround-view camera, we can more accurately identify the road features such as guard rails, lane markers, concrete barriers, other vehicles and pedestrians. More accurate identification of road features and objects should enable self-driving vehicles to better estimate safely-drivable regions and to maneuver into highway road shoulders in emergency situations.  

**Impact in other disciplines:** The computer vision algorithms, currently being developed for road feature detection, should be useful for other computer vision problems such as scene analysis.

**Airport Parking, PI: Alex Hauptmann, CMU, Students: Poyao Huang**  
**Deployment Partner(s):** Pittsburgh Airport, Grant Oliver Parking  
**Other dissemination activities:** Presentation to Airport participants  
**Technologies / Techniques:** 1: Empty parking slot detection  
We developed two different methods to detect empty parking slots in surveillance videos. The first method is using a faster RCNN model to train a car detector and inferring the empty parking slots based on the car detection results. The second method is using a modified fast RCNN model to train a car classifier for every parking slot. The second approach proved to be much less effective.  
The surveillance cameras are fixed in our project, which means we can manually label the regions for each parking slot and utilize a car classifier to detect whether there is a car in each region. The manually labelled regions are very accurate, so we now obtain good performance of empty parking slot detection after training the system with this information. We modify the fast RCNN model by using the manually-labelled bounding boxes of parking slots rather than regions generated by selective search as regions of interest (RoI).

We notice after 100,000 iterations, our model achieves 95.7% precision in empty parking slot detection.

2: Car Tracking  
We utilize object tracking algorithms to track cars in our project. In this period, we try to use Derivation of Kanade-Lucas-Tomasi Tracking Equation (KLT), Tracking-Learning-Detection (TLD) and Robust Visual Tracking and Vehicle Classification via Sparse Representation to develop a basic version of our car tracking algorithm.  
To develop a robust car tracking algorithm, we need to solve several problems. Because our smart parking system is located outdoors, our tracking algorithm needs to be robust to different light conditions and many kinds of weather, such as rain, snow and fog; One camera covers a large area, so the size of a car changes greatly as it drives away; we need to initialize a bounding box for a car before we can track it.  
To solve the above problems, we initialize bounding boxes via the last frame and during the tracking phrase, we pick up candidates based on the Gaussian distribution. We utilize Deep Convolutional Neural Network features to make our system more robust.  

**Invention / Patent applications / Licenses:** Invention disclosure preparation in progress
Other Products associated: Collected a multi-camera parking lot video data set spanning several months. Developed an app to guide cars to available spots, Created several presentations of component technologies, Create a video of the mobile phone app that guides drivers to available spots

Please explain: The video dataset will be made available to interested researchers after ground truth annotations of have been completed.

Impact: This project will improve the customer parking experience and utilization of available parking spaces.

Impact in other disciplines: Computer vision research will be impacted through techniques developed for robust tracking and object detection.

Impact on Technology Transfer: Discussions with 2 companies are in progress.


Impact: The cost analysis project evaluates the economic feasibility of large-scale deployment of current Blind Spot Monitoring (BSM), Lane Departure Warning (LDW), and Forward Collision Warning (FCW) crash avoidance systems within the light-duty vehicle fleet by conducting a cost and benefit analysis. This is done by updating any existing estimates of the maximum number of crashes that potentially could be avoided or made less severe by the three technologies (given system limitations) and examining changes in insurance collision claim frequency and severity in motor vehicles with these technologies to assess costs and benefits. The primary sources of data for this project are the 2012 GES which provides information on crashes of all severities and the 2012 FARS which provides information on fatal crashes.

Crash avoidance technologies are becoming more widespread and beginning to appear more frequently in non-luxury vehicles such as the Honda Accord and Mazda CX-9. The market penetration rate of these technologies is highly dependent on government mandates which could speed up implementation by up to 15 years. An important research goal for transportation professionals is to investigate the economic impact of partial vehicle automation, in order to aid policymakers in identifying effective policies to help stimulate automated vehicle deployment and provide a smooth transition to a fully automated light-duty vehicle fleet. The results from this analysis can be used to determine if it is economically feasible to equip the entire light-duty vehicle with crash avoidance technologies due to benefits from prevented and less severe crashes, given
current system limitations. Sensitivity analyses are conducted to examine how a change in crash cost and frequency and technology cost impact the annual net-benefit. The economic impact that these technologies will have on private insurers, households, third-parties (charities, etc.), and congestion are reported.

Impact in other disciplines: An important research goal for transportation professionals is to investigate the economic impact of partial vehicle automation, in order to aid policymakers in identifying effective policies to help stimulate automated vehicle deployment and provide a smooth transition to a fully automated light-duty vehicle fleet. Determining the annual net-benefit of equipping all light-duty vehicles with blind spot monitoring, lane-departure warning, and forward collision warning crash avoidance technologies should provide a basis for policy makers to begin to consider when and if any regulations regarding these technologies should be put in place which would have an impact on market penetration and insurance rates and vehicle cost.

Impact on Technology Transfer: The cost-benefit study estimates the benefits to private insurers, public, revenues, and household from prevented and less severe crashes from the fleet-wide adoption of three different crash avoidance features. There are many insurance companies that offer discounts for ABS, this research could help insurers make informed decisions when considering offering discounts for those with blind spot monitoring (BSM), forward collision warning (FCW), and lane departure warning (LDW), and the magnitude of discounts for each technology. For example, FCW could impact the largest number of crashes by far and is the most effective (as shown by observed insurance data) out of all three technologies, and as a result insurance companies could consider providing a greater discount for this technology than BSM and LDW. NHTSA should also find this research useful when developing regulations and guidelines for automakers, as the results state that it is feasible from an economic perspective to equip all vehicles with level 1 crash avoidance technologies.

Monitoring and Predicting Pedestrian Behavior at Traffic Intersections, PI: Luis E. Navarro-Serment, CMU, Co-PI: Martial Hebert, Students: Meghana Reddy Guduru

Deployment Partner(s): Rapid Flow Technologies, LLC, 124 South Highland Ave Suite 206, Pittsburgh PA 15206, Provides: access to video data from traffic intersections, expertise on practical issues.


Technologies / Techniques: We have developed a video processing pipeline to detect people from images, which is customized for operation with the type of cameras currently used to monitor vehicular traffic.

We have also developed an approach to calibrate traffic cameras on-site, which is inexpensive in terms of time and logistics; does not require expensive instruments or software packages; uses a low-cost custom-made laser scanner; and can be performed by personnel with minimal training.

Finally, building upon the calibration approach, we have developed a methodology to determine the location of a person in an image with respect to the geometry of the traffic intersection, and considering all the cameras covering the intersection.

Invention / Patent applications / Licenses: Nothing to report
Other Products associated: Low-cost 3D scanner for traffic camera calibration.

Please explain: To support the calibration approach and the methodology for person location within the intersection, we designed and constructed a low-cost 3D scanner. This scanner, built around a low-cost 2D laser range finder, allows us to obtain three-dimensional models of traffic intersections quickly and accurately, but at a fraction of the cost of more expensive scanners commercially available. We plan to make our design (i.e. mechanical design and accompanying software) freely available to other researchers in the near future. This will facilitate the adoption of our camera calibration methodology by other agencies.

Impact: The cost analysis project evaluates the economic feasibility of large-scale deployment of current Blind Spot Monitoring (BSM), Lane Departure Warning (LDW), and Forward Collision Warning (FCW) crash avoidance systems within the light-duty vehicle fleet by conducting a cost and benefit analysis. This is done by updating any existing estimates of the maximum number of crashes that potentially could be avoided or made less severe by the three technologies (given system limitations) and examining changes in insurance collision claim frequency and severity in motor vehicles with these technologies to assess costs and benefits. The primary sources of data for this project are the 2012 GES which provides information on crashes of all severities and the 2012 FARS which provides information on fatal crashes.

Crash avoidance technologies are becoming more widespread and beginning to appear more frequently in non-luxury vehicles such as the Honda Accord and Mazda CX-9. The market penetration rate of these technologies is highly dependent on government mandates which could speed up implementation by up to 15 years. An important research goal for transportation professionals is to investigate the economic impact of partial vehicle automation, in order to aid policymakers in identifying effective policies to help stimulate automated vehicle deployment and provide a smooth transition to a fully automated light-duty vehicle fleet. The results from this analysis can be used to determine if it is economically feasible to equip the entire light-duty vehicle with crash avoidance technologies due to benefits from prevented and less severe crashes, given current system limitations. Sensitivity analyses are conducted to examine how a change in crash cost and frequency and technology cost impact the annual net-benefit. The economic impact that these technologies will have on private insurers, households, third-parties (charities, etc.), and congestion are reported.

Impact in other disciplines: We anticipate that our research will have an impact on adaptive traffic light control systems, which currently operate entirely based on information pertaining vehicular traffic. Our work will alleviate the need for timely and accurate information about pedestrian traffic. This is particularly important at locations where it is not uncommon to find more pedestrians than vehicles during certain times of the day.


Deployment Partner(s): City of Pittsburgh; Axis Communications AB

Website: http://www.contrib.andrew.cmu.edu/~bpires/pedssurtrac.html


Other Products associated: Data & Research Material, Instruments or equipment, Software / Netware

Please explain: This project entails equipping one Surtrac intersection with cameras that will collect pedestrian activity and intent to cross intersection. For this purpose, we will collect and label public video data. We will also further develop data labeling software.

Impact: The objective of this project is to make Surtrac, the real-time adaptive traffic signal control system, aware of pedestrian traffic. Phase 1 of this one-year project will analyze pedestrian traffic at multiple Surtrac deployments. Phase 2 will focus on an intersection already equipped with Surtrac system in the Oakland / East Liberty region and will add additional sensing and processing capabilities to determine the presence of pedestrians waiting to cross the intersection.

Impact in other disciplines: In addition to the primary impact on transportation planning, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the bike and pedestrian detection problem, as well as a large body of classified visual data.

Impact on Technology Transfer: As more intersections are instrumented with smart traffic control systems, there is a growing need for pedestrian detection as an input for such control systems. We expect that the current project, and its associated deployment, will mature our detection technology to the point where it is ready for commercialization.

Measuring Pedestrian Wait Times at Intersections, PI: Bernardo Pires, CMU, Co-PI: Mehmet Kocamaz, Students: Christopher Kaffine, Jian Gong

Deployment Partner(s): City of Pittsburgh; Bike Pittsburgh


Other dissemination activities: Presentation to key Bike Pittsburgh Stakeholders, 04.22.2015

Website: http://www.contrib.andrew.cmu.edu/~bpires/pedwaittime.html

Technologies / Techniques: Image processing methods for automatic pedestrian detection on top-down camera views.

Other Products associated: Data & Research Material, Instruments or equipment, Software / Netware

Please explain: During December of 2015, this project used custom assembled hardware to collected a dataset of top-down views showing pedestrians waiting at one Pittsburgh intersection. Purpose-built software was created to process this dataset and
determine the average length of time that pedestrians were waiting to cross the intersection.

**Impact:** The objective of this project is to bring insight into the impact that smart traffic light systems have on the pedestrian flow. As more and more intelligent traffic control systems are deployed it is paramount to determine what effect they have on pedestrian flow, both for planning and safety purposes.

**Impact in other disciplines:** In addition to the primary impact on the field of transportation, this project develops novel image processing methods for detection of humans in videos.

**Impact on Technology Transfer:** The algorithms developed in this project further augment the domain knowledge at CMU for the optimal construction of pedestrian detection systems. As the field matures, we expect that commercial applications will become viable.

**Automatic Counting of Pedestrians and Cyclists, PI:** Bernardo Pires, CMU,

**Students:** Christopher Kaffine, Jian Gong, Ganesh Kumar Nunnagoppula, Dhruv Saksena

**Deployment Partner(s):** City of Pittsburgh, Department of City Planning; Bike Pittsburgh


**Other dissemination activities:** Participation and Device Demonstration at the ITS America Annual Meeting. May 31st, 2015 to June 3rd, 2015.
UTC Faculty Presentation, 09.01.2015
Presentation to City of Pittsburgh Officials, 09.10.2015
Participation on T-SET Consortium, 11.11.2015

**Website:** http://www.contrib.andrew.cmu.edu/~bpires/bikeped.html


**Invention / Patent applications / Licenses:** Nothing to report

**Other Products associated:** Data & Research Material, Instruments or equipment, Software / Netware

**Please explain:** This project entails created a data collection device, the collection of public video data (more than 75 hours have been collected), and the creation of data labeling software as well as automatic counting software.

**Impact:** The primary impact of this project is to provide actionable data for government officials and advocates that promote bicycling and walking. In particular, the partnership
with the City of Pittsburgh intends to collect data that is relevant for city planning. As part of this effort, a full week of rush hour data has been collected and analyzed for the City of Pittsburgh. This data will inform the usage of the newly created bike lane at the intersection of Craig St and Bayard St.

**Impact in other disciplines:** In addition to the primary impact on transportation planning, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the bike and pedestrian detection problem, as well as a large body of classified visual data.

**In-Car Cell Phone Detection, PI:** Bernardo Pires, CMU, **Students:** Christopher Kaffine, Jian Gong


**Other publications, conference papers and presentations:** Testimony on “Enhancing the Safety of Highway Workers, Drivers and Pedestrians” at the Joint Hearing before the Senate Transportation Committee and the House Transportation Committee

**Other dissemination activities:** Participation at the ITS America Annual Meeting. May 31st, 2015 to June 3rd, 2015.

**Website:** [http://www.contrib.andrew.cmu.edu/~bpires/phonedetect.html](http://www.contrib.andrew.cmu.edu/~bpires/phonedetect.html)


**Other Products associated:** Data & Research Material, Software / Netware

**Please explain:** This project created a dataset of users handling cell phones inside vehicles as well automatic phone detection software.

**Impact:** The primary impact of this project is a contribution to in-car safety and crash prevention by creating cost-effective methods for distraction detection due to use of electronic devices.

**Impact in other disciplines:** In addition to the primary impact on in-car safety and distraction detection due to use of electronic devices, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the detection of electronic displays inside the car, as well as a body of classified visual data.

**Accident Investigation with 3D Models from Images, PI:** Christoph Mertz, CMU, **Students:** Abhinav Girish

**Deployment Partner(s):** Pittsburgh Police Department: provide us with crashed cars for testing our algorithms, give feedback on our technology

**Other publications, conference papers and presentations:** Invited presentation at WREX 2016 World Reconstruction Exposition

**Other dissemination activities:** Website with description of system, downloads and documentation of software, downloads of 3D models.

Presentation of technology to industry, government, and academic visitors.

**Website:** [http://www.cs.cmu.edu/~reconstruction/](http://www.cs.cmu.edu/~reconstruction/)
Technologies / Techniques: We have developed technologies that can reconstruct 3D accident scenes. In particular we have refined the method to reconstruct inside and outside of the crashed vehicle in one model and modeling intricate and difficult-to-reach parts of the vehicle. We have also done data collection to produce 3D movies of accidents. All our code and description of technology is available for free on our website.

Other Products associated: Database of 3D models of crashed vehicles, software and documentation of the technology

Please explain: Models, software and documentation are available for download from our website

Impact: The developed technology and its free availability on a website can significantly reduce the cost of 3D accident reconstruction for investigators.

Impact in other disciplines: The technology can also be used in related fields like crime scene investigation, inspection of buildings, etc.

Impact on Technology Transfer: Several accident investigators have downloaded our code and testing its applicability to their work.

City Road Inspection, PI: Christoph Mertz, CMU, Co-PI: Nothing to report, Students: Abhinav Girish, Peter Wei, Luyao Hou

Deployment Partner(s): City of Pittsburgh, Cranberry Township, North Huntington Township - these government entities collect road data that we analyze, they provide us insight into their work practices and give us feedback.

Other dissemination activities: The project was presented to many industry, government, and academic visitors.

Website: http://www.cs.cmu.edu/~road/

Technologies / Techniques: We have developed road surface assessment, traffic sign detection and assessment, and we are still developing sign retroreflectivity measurements with smartphones.

Invention / Patent applications / Licenses: We have filed following invention disclosures:
CMU Invention Disclosure 2017-033 entitled “Road infrastructure data pipeline,”
CMU Invention Disclosure 2017-008 entitled “Visual texture detection for road inspection.”
CMU Invention Disclosure 2017-029 “Stop sign detection and assessment”
CMU Invention Disclosure "Data collection app for android cameras and mobile devices"

CMU is in negotiation with a startup to license these inventions

Other Products associated: Databases: maps of road damage, traffic signs, and damaged traffic signs. These are shared with City of Pittsburgh, Cranberry Township and North Huntington Township.

Please explain: The city and townships collect the raw data, we analyze the data and return the inventory and assessment maps back to them. They give us feedback on them.
**Impact:** We have spun out a startup that will commercialize this technology. Invention disclosures have been filed and the license agreements are being negotiated. The product will significantly reduce the cost of infrastructure inventory and assessment.  

**Impact in other disciplines:** The data collected and maps that have been created can be used in other computer vision projects.  

**Impact on Technology Transfer:** A start-up has been created to commercialize the technology.  

**Low-Cost Vehicle Localization for Driving and Mapping, PI:** John M. Dolan, CMU, **Students:** Adam Werries  

**Deployment Partner(s):** GM R&D, Warren, MI; In-kind support via use of test vehicle  


**Website:** http://www.ri.cmu.edu/research_project_detail.html?project_id=775&menu_id=261  

**Technologies / Techniques:** Our current work is on reducing computation through focused sampling and minimal replanning; and generation of smooth trajectories across the range of highway, urban, and evasive maneuver scenarios. The motion planner requires high-accuracy localization. For autonomous vehicles, navigation systems must be accurate enough to provide lane-level localization. High-accuracy sensors are available but not cost-effective for production use. Although prone to significant error in poor circumstances, even low-cost GPS systems are able to correct Inertial Navigation Systems to limit the effects of dead reckoning error over short periods between sufficiently accurate GPS updates. Kalman filters are a standard approach for GPS/INS integration, but require careful tuning in order to achieve quality results. This creates a motivation for a Kalman filter which is able to adapt to different sensors and circumstances on its own. Typically for adaptive filters, either the process (Q) or measurement (R) noise covariance matrix of Kalman filters is adapted, and the other is fixed to values estimated a priori. We show that intelligently adapting both matrices in an intelligent manner can provide a more accurate navigation solution.  

**Other Products associated:** Software  

**Please explain:** The described techniques for low-cost localization have been coded in C++ and tested in both closed-course and real-world scenarios in the Pittsburgh area, including the Oakland university neighborhood of Pittsburgh, which is a fairly dense urban environment.  

**Impact:** The developed localization techniques are not yet sufficiently accurate to provide lane-level localization. However, in conjunction with odometry and map-matching, they have the potential to make it more cost-effective to provide localization for autonomous and semi-autonomous vehicles at an affordable price.  

**Impact in other disciplines:** High-accuracy, low-cost localization for outdoor robots is a valuable technology that can be used for many other types of field robots besides autonomous cars.  

**Marcellus Shale Traffic, PI:** Robert P Strauss, CMU, **Students:** Nauman Afridi
Deployment Partner(s): PA. State Police and Administrator of the PA Courts

Journal Technologies / Techniques: A relational and spatial database has been generated which shows all road improvements in PA due to activities of the natural gas industry.

Other Products associated: A research report and journal articles are contemplated once we receive the over weight citation data.

Impact: Coincidental with this project has been the establishment and deployment of 15 mobile weight monitoring units throughout the Commonwealth. Our project could well have prompted transportation policy makes to upgrade the number of weight monitoring stations in the Commonwealth.