Technologies for Safe and Efficient Transportation
A U.S. DOT UNIVERSITY TRANSPORTATION CENTER
Carnegie Mellon University
UNIVERSITY OF PENNSYLVANIA
Program Progress Performance Report for University Transportation Centers

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       Research and Innovative Technology Administration
       UTC Program

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               National University Transportation Center for Safety

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Signature: ________________________________
**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

Other Research, Development and Deployment activities include:

On October 13, 2016, the first ever White House Frontiers Conference was hosted in Pittsburgh at Carnegie Mellon University on Thursday, October 13th. The purpose of the conference was to explore the future of innovation here and around the world. The UTC’s driverless car was featured.

On November 29, 2016, T-SET held our Advisory Council meeting where we brought together leading thinkers in industry, government, and community to discuss the future of transportation.

On January 31, 2017, UPenn held a T-SET Consortium Meeting in Philadelphia to bring together researchers and deployment partners from government, industry and community.

On March 9, 2017, CMU hosted the SMART Belt Coalition on campus. Representatives from PA Turnpike, PennDOT, Michigan Turnpike, Ohio DOT, Ohio Turnpike, Michigan Turnpike, Michigan DOT where present along with Ohio State and Univ. of Michigan.

Other T-SET UTC Research, Development and Deployment Activities included participating or presenting at:

- TRB Symposium on Transformational Technologies
- PA AV Testing Task Force
- Martin O'Malley
- Ford Visit
- INRIX Meeting
- Discussion with HERE
- Cisco Meeting
- RETRC Congressional Meetings
- CUTC Executive Committee Meeting
- CUTC Banquet
- UTC CUTC Winter Meeting
- TRB Annual Meeting
- Seminar from Kara Kockelman
- Ohio Smart Mobility Initiative Meeting
- Karina Ricks, City Mobility Director
- PA Legislative Joint Transportation Committees Hearing on HAVs
- ITSA Congressional Visits
- Avis Budget Meeting

Education and Workforce Development

During this reporting period, we established a Diversity in Transportation Fellowship in the CMU College of Engineering for PhD students. This Fellow will be active with the UTC and work with UTC researchers throughout the course of their studies.

On Friday, March 31st, T-SET UTC's Raj Rajkumar spoke at the Energy Innovation Center as part of panel for Pittsburgh Innovates, one of the city's many Inclusive Innovation week events. The discussion revolved around innovations bringing new opportunity, talent, and jobs to the
greater Pittsburgh area. Rajkumar was joined by business leaders from various sectors, Congressmen Mike Doyle and Tim Murphy, and Mayor Peduto's Chief of Staff, Kevin Acklin.

T-SET UTC also held the following Faculty Seminars which are available on our Learning Channel:

- **From Set-and-Forget Traffic Control to Connected Midas: A Possible Future of Proactive Traffic Management Systems**
  Pitu Mirchandani, Friday, March 24, 2017

- **Heaven or Hell? Which Way Forward With Self-driving Cars?**
  Robin Chase, Tuesday, November 29, 2016

- **Human Mobility Analytics and Services: Insights from a Ride Sharing Service**
  John Paul Shen, November 17, 2016

- **Getting Things Done: A New Way of Governing**
  Martin O’Malley, November 16, 2016

- **Park Smart: Parking Space Availability Monitoring at Pittsburgh International Airport**
  Alexander Hauptmann, November 9, 2016

- **Computer Vision for Safer Biking and Walking**
  Bernardo Pires, November 2, 2016

- **Smart Transportation: Small Changes for Big Impact**
  Paul Mackie, October 6, 2016

Other T-SET education and workforce development activities included presenting or participating in the following:

- SPC Freight Forum semi-annual meeting
- Guest Seminar from Kara Kockelman
- Women’s Transportation Seminar CMU UTC Lab Tour
- CAV Policy working group Meeting
- Visit from Pitt Russian Delegation
- Tepper Business and Tech Club Industry Night
- City of Pittsburgh’s Inclusive Innovation Week CMU Transportation Technology Tour
- Pitt Ohio Tour

**Technology Transfer & Collaboration**

UTC Consortium Meeting was held on November 3, 2016 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.

On November 19, 2016, CMU hosted the first Transportation Camp in Pittsburgh, with over 100 participants from around the region. Transportation Camp is an unconference that started in DC.
On December 16, 2016, Christoph Mertz, UTC research faculty, and Courtney Ehrlichman, UTC Deputy Executive Director, licensed technology from CMU and formed a company called RoadBotics.

Other T-SET technology transfer and collaboration activities included presenting or participating in the following:

- ITSA Leadership Circle and Board Meeting
- Rick Johnson from Hillman Company Cadillac Ride
- New Cities Summit
- Meeting with AAF Foundation and City Planning
- Norwegian Delegation Visit
- Tri State Shale Initiative
- Advanced Mobility Summit
- National League of Cities Annual Meeting
- Modern Transit Partnership Meeting
- ITS America Board Meeting
- Pennsylvania Digital Government Summit
- Singapore Visit
- Smart Cities Summit USPS
- Council of State Governments National Meeting
- Pennsylvania Society
- Consumer Electronics Show
- DC Auto Show
- Pittsburgh’s BRT Meeting
- SXSW Conference
- Engineers Society of Western PA Banquet

**Diversity**

On Friday, March 31st, Traffic21 and T-SET/UTC’s Stan Caldwell and Courtney Ehrlichman hosted a tour of the technologies housed in CMU’s Navlab. The tour was held in conjunction with the city of Pittsburgh’s Inclusive Innovation week.

On Thursday, March 23rd, Traffic21’s Courtney Ehrlichman and interns Amanda Johnson and Ngani Ndimbie attended Pittsburgh’s first annual Women in Transportation Scholarship Gala, where PennDOT’s first female Secretary of Transportation, Leslie Richards was the keynote.

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
- Established Diversity in Transportation Fellowship

**Products**

**General Program Products**
- UTC website [www.utc.ices.cmu.edu](http://www.utc.ices.cmu.edu)
- 6716 blog posts
- Consistent weekly distribution of T-SET email newsletter, 1,798 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**

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<td>Pittsburgh-based Carnegie Robotics to Collaborate with GPS Maker on Automation</td>
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<td>March 28, 2017</td>
<td>Traffic21 Faculty Seminar/webinar with Dr. Erick Guerra</td>
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<td>In Rare Robotics Gathering, Ventures Like Uber, Argo AI Reflect on Progress, Competition</td>
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<td>March 15, 2017</td>
<td>Six Months Of Self-Driving Car Rides In Pittsburgh: A Look Back</td>
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<td>America’s Failing Infrastructure Is A Serious Problem For Autonomous Vehicles</td>
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<td>RoadBotics, CMU/Traffic21 Spin-off, Places 2nd at SXSW Mayor's Pitch Competition</td>
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<td>Survey Finds Public Slow To Accept Self-Driving Vehicles</td>
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<td>The Way We Talk About Autonomy Is a Lie, and That’s Dangerous</td>
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<td>Meet Delphi, The Self-Driving Car Company In Pittsburgh That You Probably Don’t Know Much About</td>
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<td>How I Became The Director Of Engineering At Lyft: Jill Wetzler</td>
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<td>One Of Uber’s Top Self-Driving Engineers, Raffi Krikorian, Is Stepping Down</td>
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<td>With Ford venture, a talent war for engineers heats up</td>
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<td>Ford Bets $1B on Startup Founded by former CMU Robotics Alumni</td>
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<td>CMU spin-off RoadBotics is infrastructure-focused</td>
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<td>February 9, 2017</td>
<td>CMU: Car-Sharing Won't Kill the Auto Industry</td>
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<td>February 8, 2017</td>
<td>Take a drive in Google’s newest self-driving car</td>
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<td>February 2, 2017</td>
<td>Uber expects to see more growth in Pittsburgh</td>
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<td>Why using a mobile phone while driving is so dangerous ... even when you're hands-free</td>
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<td>January 26, 2017</td>
<td>Model driverless car regulations after drug approval process, CMU AI ethics experts argue</td>
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<td>January 23, 2017</td>
<td>Colleges are essential part of 'smart city' movement</td>
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<td>January 23, 2017</td>
<td>CMU team’s high-speed transit idea to get a test in SpaceX competition</td>
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<td>January 20, 2017</td>
<td>CMU Joins “Smart Belt Coalition” with PA, OH, MI to Collaborate on Connected/Automated Vehicle Initiatives</td>
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<td>January 20, 2017</td>
<td>Obama’s manufacturing initiative comes to CMU</td>
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<td>Former Microsoft executive and noted AI expert Qi Lu joins Baidu as COO</td>
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<td>Amazon opens join tech companies with Pittsburgh office</td>
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<td>January 20, 2017</td>
<td>When Uber invests in an Indian startup, who really wins?</td>
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<td>January 13, 2017</td>
<td>$250 Million To Support Advanced Robotics Venture Led by CMU</td>
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<td>January 12, 2017</td>
<td>Beverly Hills Goes for Self-Driving Transit</td>
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<td>January 6, 2017</td>
<td>Rubber meets the RoadBotics in Pittsburgh</td>
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January 6, 2017 - PennDOT plays role in self-driving testing site proposal
January 6, 2017 - How To Find A Computer Bug In Self-Driving Car Software
January 4, 2017 - PennDOT seeks to make Pennsylvania proving ground for automated vehicles
January 3, 2017 - He's Helping Pittsburgher Drivers Get The Green Light
January 3, 2017 - The biggest auto parts supplier says there are 3 big hurdles holding back self-driving cars
December 22, 2016 - Silicon Valley Dominating Self-Driving Tech? Motor City Says Not So Fast
December 22, 2016 - University at Buffalo gets federal grant to explore driverless car technology
December 19, 2016 - Self-driving cars will be safer drivers than I am, but I'm still nervous in them
December 19, 2016 - The Big Bang of autonomous driving DARPA Challenge
December 16, 2016 - PA considers new rules for self-driving cars
December 16, 2016 - CMU's Rajkumar Named Fellow of National Academy of Inventors
December 14, 2016 - Feds move to require new cars to 'talk' to each other
December 13, 2016 - Uber has lost three of its top self-driving engineers
December 13, 2016 - Google Puts the Brakes on Its Autonomous Bubble Car
December 12, 2016 - CMU grant shows Pittsburgh's growth as a transportation innovation center
December 8, 2016 - Carnegie Mellon University awarded $14 million federal grant
December 8, 2016 - Smart Cars And Traffic Control And Assistive Technology, Oh My! DOT Taps CMU For 21st Century Tech
December 7, 2016 - How the U.S. Postal Service could enable smart cities with CMU
December 1, 2016 - Pittsburgh pulls ahead of Detroit in driverless tech race
December 1, 2016 - Pittsburgh's smart city efforts include autonomous driving, open data, and renewable energy
November 30, 2016 - Pittsburgh's smart city efforts include autonomous driving, open data, and renewable energy
November 30, 2016 - How Sensors, Smartphones Can Bring the Road Solutions We Need
November 28, 2016 - Meet ALVINN, the self-driving car from 1989
November 23, 2016 - Smart City Initiatives Rolling Out Across the U.S.
November 17, 2016 - Delphi Automotive's Pittsburgh Connection Has Leg Up in Race to Driverless Technology
November 17, 2016 - Facebook acquires emotion detection CMU startup FacioMetrics
November 16, 2016 - RedChairPGH empowers women in technology with event and advocacy campaign
November 11, 2016 - How can Pittsburgh's Port Authority tackle a common public-transit problem?
November 11, 2016 - CMU to bringing Transportation Unconference to PGH on November 19th
November 11, 2016 - Carnegie Mellon's 1986 Self-Driving Van Was Adorable
November 11, 2016 - Carnegie Mellon to Study Ethical Issues in Smart Tech, Robotics
November 11, 2016 - 11/16: Traffic21/Metro21 Presents Martin O'Malley: Getting Things Done: A New Way of Governing
**Non-Intrusive Driver Distraction Monitoring Using Vehicle Vibration Sensing, PI:** Hae Young Noh, CMU, **Co-PI:** Pei Zhang, **Deployment Partner(s):** Renault

**Anticipated Research Outcomes:** "In this project, we will use inertial sensors embedded in the vehicle seat for recognizing driver’s distraction states. These includes physical distractions (such as texting and tuning the radio) and cognitive distractions (including stress, fatigue, etc.). Advantages of the inertial sensor based driver monitoring system come from its simple and non-intrusive nature (i.e. no need for drivers to wear a device).

- Currently, we have already built a sensing platform that can capture the ""micro-motion"" (heart-beat, posture, and breathing-rate) from the occupant of the vehicle.
- Preliminary data are collected using multiple sensors with vehicle under various driving conditions, including highway, local, parking-lot, stop and go.
- Data collected from passengers of the vehicle while speaking, moving, and generally sitting in the car.

Moving forward, we will focus our effort on developing data processing methods to extract detailed heart rate rhythm variability (for stress detection, etc.), and distraction related movement of drivers (for phone usage detection, etc.). The main challenge resides in high noise due to moving vehicles and sensing location constraints. To address these challenges, we plan to utilize multiple sensor nodes, high-resolution and high frequency data with hybrid modeling approach to minimize uncertainties in signal processing and obtain reliable information through modeling of data as well as vehicle and human responses. We will experiment in real-vehicles during driving conditions to ensure real-world applicability of our system."

**Impact:** The results from this project will lead to understanding the driver's physiological states including distraction, which will lead to safer vehicles and safer roads. In particular, as self-driving cars become more prevalent, such information becomes more important to pass control between driverless and driver-operated modes. Driver distraction is responsible for more than a quarter of the 1.3 million deaths and 50 million injuries from road traffic accidents. It is the leading cause of death for the young. With the advent of mobile devices and mobile entertainment, this trend is only projected to increase. To reduce the distraction, the vehicle must first understand the distraction level of a user. In the past, many single-point on-body sensors and camera systems have been proposed to measure in car driver status (such as sleep, etc.) but these approaches are often limited to certain environments or require intrusive sensors on drivers that are difficult to deploy in reality.

**Did Research Results Confirm or Change Practice?**
Preliminary data confirmed that micromotion can be used to extract heart-rate under different occupant and vehicle scenarios. Most importantly, the results confirmed that the occasional time-variant noise the data experiences caused by large movements can be identified and removed.

The results also suggest that the sensors are much more sensitive to the micro-motion than first anticipated. Thus, talking and radio noise was incorporated in the testing scenarios to determine the interference with the heart-rate signals. Separating these signals could require sensor fusion with microphone inputs in the audio environment.

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

Issues: Noise from the radio and human talking had a stronger influence than required. This is being addressed with sensor fusion from audio sensors.

Accomplishments:
- We have built a sensing platform that can capture the "'micro-motion'" (heart-beat, posture, and breathing-rate) from the occupant of the vehicle.
- Preliminary data are collected using multiple sensors with vehicle under various driving conditions, including highway, local, parking-lot, stop and go.
- Data collected from passengers of the vehicle while speaking, moving, and generally sitting in the car.

Multimodal Detection of Driver Distraction, PI: Maxine Eskanazi, CMU, Co-PI: Louis Phillipe Morency, Student(s): Shrimai Prabhumoye Deployment Partner(s): Yahoo!

Anticipated Research Outcomes: The outcome of the research for this period is the first set of recordings of the multimodal distraction database. The database will be shared with the research community.

Anticipated Impacts: This database should impact the field in the way we take variables that cause and result from distraction into account. At present one or two variables are examined at a time, rather than looking at the whole picture. With this tightly controlled database, it is possible to examine the affects that road conditions, speech and head and eye movements have on one another and then combine them with the driving out come as measured by the vehicle (steering, braking, etc).

Did Research Results Confirm or Change Practice? They confirm the fact that we can get highly controlled data using this approach.

Web Links: http://utc.ices.cmu.edu/utc/projectitem.asp?ID=167

Issues: Nothing to report
**Accomplishments:** First part of dataset has been recorded. We have: driving the simulator, two questionnaires, annotating the recording - for each subject.


**Accident Investigation with 3D Models from Image, PI:** Christoph Mertz, CMU. **Deployment Partners:** Pittsburgh Bureau of Police, Texas A&M Transportation Institute (TTI).

**Monitoring and Predicting Pedestrian Behavior Using Traffic Cameras, PI:** Luis E. Navarro-Serment **Co-PI:** Martial Herbert **Deployment Partners:** Rapid Flow Technologies

**Anticipated Research Outcomes:** We anticipate the creation of a vision-based pedestrian detection, tracking, and prediction capable of running in real time, where the location of all pedestrians in or near the intersection is determined using calibrated monocular cameras. Additionally, we anticipate the creation of techniques to increase the robustness of vision-based detectors for different illumination conditions.

**Anticipated Impacts:** The approaches developed in this effort move us closer to provide traffic intersections with the ability to monitor pedestrian activity. Most traffic intersections currently lack awareness of pedestrian traffic: their perception abilities—when available—are usually limited to the detection of vehicles at very specific places. Video cameras can be used to monitor pedestrian traffic in a setting where a static camera that has an unobstructed view of the road is used to detect and track pedestrians. Typically, a single camera cannot cover the entire area, so multiple cameras are used at each intersection. However, simply detecting pedestrians is not enough: it is also necessary to accurately determine their location within the area surrounding the intersection. The work done in 2016 is key to determine locations using the monocular cameras used for traffic monitoring. 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.

**Did research results confirm or change practice?:** 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.

**Weblinks:** none
Issues: none

Accomplishments: 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.


Anticipated Research Outcomes: In the long term, this research will shed light on whether and when vehicular networks deployed for safety purposes can also be used to provide Internet access in a more cost-effective way than is possible with today's technology, (whether sharing of infrastructure between government agencies seeking to improve highway safety and providers of Internet services can save money, and if so what pricing strategies government agencies should adopt, and how spectrum should be allocated, shared and used for these purposes.

So far, we have shown that Internet access over DSRC-based vehicular networks will be cost-effective in regions where population density is sufficiently high, e.g. it can be an attractive option in cities by not in highly rural areas. We have also found that in regions where it is cost-effective, infrastructure sharing between state and local government agencies and commercial companies can be quite cost-effective.

Anticipated Impacts: The objective of this project is to make Surtrac, the real-time adaptive traffic signal control system, aware of pedestrian traffic. The primary impact of this project will be to increase the efficiency of the real time traffic control system. Initially, the project will analyze pedestrian traffic at multiple Surtrac deployments. Followed by a focus on an intersection already equipped with Surtrac system in the Oakland / East Liberty region with the addition of sensing and processing capabilities to determine the presence of pedestrians waiting to cross the intersection. Further, this project is expected to have an impact in other disciplines by pushing forward the state of the art on the Computer Vision and Machine Learning Fields. This will be achieved by creating new classifiers tailored specifically to the bike and pedestrian detection problem, as well as a large body of classified visual data.

Did research results confirm or change practice?: The research results strongly support our original premise that it is not only possible, but also effective to use cameras mounted at intersections to determine pedestrian presence. 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. Although deployment was not possible before the end of the 2016
calendar year (see issues below) we believe that this project as helped mature the pedestrian detection technology towards the point where it is ready for widespread adoption.

Websites: http://www.contrib.andrew.cmu.edu/~bpires/pedsSurtrac.html

Issues: The software and hardware are ready for deployment and the intersection to be equipped has been approved by all stake-holders. However, it was not possible to achieve deployment before the end of the 2016 calendar year as we are awaiting permission from the City of Pittsburgh for final installation, which we expect to achieve during the 2017 calendar year.

Accomplishments: T-SET Student of the Year Award for Christopher Kaffine


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Anticipated Impacts: This work is still underway, but in baseline scenarios, we find that this form of sharing can be used to pay for 20% of the total nationwide cost of roadside infrastructure required for safety applications, although some regions benefit more from these arrangements than others. We hope that many state and location transportation agencies in regions where infrastructure sharing is effective will explore the creation of public-private partnerships based on our work, as this would both save tax-payer dollars and facilitate the roll-
out of less expensive Internet service for mobile users. Our results should also inform and
guide pricing strategies that government agencies should use in these public-private
partnerships.

Did research results confirm or change practice?:
Research results have not yet changed practices, but it is early, in part because the research is
still underway and in part because the U.S. Department of Transportation has not yet decided
whether to require DSRC technology in new vehicles. Until that decision is made, the
strategies for deploying DSRC-equipped roadside infrastructure are theoretical. However,
some of our results have been presented to decision-makers at the highest level, including the
Chairman of the U.S. Federal Communications Commission, and Pennsylvania Transportation
officials.

Websites: https://users.ece.cmu.edu/~peha/vehicular.html
https://users.ece.cmu.edu/~peha/papers.html#Vehicular
https://www.youtube.com/watch?v=mYgeEiXHs4M

Issues: No problems have arisen. We are making very good progress, although there is a lot
more useful work to do.

Accomplishments: We have published in one IEEE vehicular technology conference, and a
paper has been accepted for the next conference. We have repeatedly briefed government
leaders involved in making decisions about vehicular networks, including the Chairman of the
U.S. Federal Communications Commission.

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). Other publications, conference
papers and presentations: Building an accessible, low-stress, safe, and sustainable, bicycle
infrastructure network for City of Pittsburgh, The 10th TRB University Transportation Centers

Anticipated Research Outcomes: Every day, a mix of drivers, pedestrians, and cyclists use
the streets and sidewalks of a given city. In order to plan their routes, many people use
mapping applications such as Google Maps or Map Quest. These programs provide users a
route to their destination based primarily on shortest distance and traffic congestion. However,
this distance-based algorithm does not work equally well for all modes of transportation.

In particular, cyclists must account for factors that are usually not considered for automobiles,
such as: the slope of a road due to the increased effort required to navigate hills, safety
concerns due to the limited protection offered by a bicycle, the existence or absence of
designated bike lanes, and mobility concerns with the transit coverage. In order to address such
concerns, this research aims to create an application that fuses multi-modal data sources to
assess bike safety/mobility, and allows cyclists to customize the weights of attributes such as
safety or the slope of roads. This novel weighting system would allow users to actively choose
routes based on safety and personal preferences.
To accomplish this goal, we have gained access to massive data for the Pittsburgh region which include, but are not limited to, crash data, incident data, traffic volume/speed data, transit data, and geographic elevation data. We will apply statistical models to establish the relationship between cyclist crash risk and various explanatory variables.

**Anticipated Impacts:** Pittsburgh region. Each street will have a value for each variable based on current data.

We will then deploy an online web application in Pittsburgh to present those road-cycling scores and recommend routes. Recommendations will be made based on customized user weighting of each variable, so that each cyclist can plan according to his or her own priorities and be more knowledgeable about the safety of the chosen route.

In addition to making a web application, the results of the statistical models can be used by local authorities. By knowing which variables are related to crashes, officials can know what measures are more likely to improve bicycle safety and can install appropriate bicycle infrastructure as a result.

**Did research results confirm or change practice?:** Not yet, but we hope to change practice for bike trips and bike facility planning once the research is complete.

**Weblinks:** None

**Issues:** None

**Accomplishments:** We have submitted some of our results to a UTC spotlight conference, and presented some initial results there.


**Sensor-based Assessment of the In-Situ Quality of Human-Computer Interaction in Cars, PI:** SeungJun Kim, **Co-PI:** Anind K. Dey, **Deployment Partner(s):** TK (TAKATA) Holdings Inc., Hyundai Motor Group (Human Factors and Devices Research Team in the R&D Division), KETI (Korea Electronics Technology Institute), UNIST (Ulsan National Institute of Science and Technology), Cindy Cohen School of Driving, LLC. **Journal Publication(s):** 1. Leveraging Human Routine Models to Detect and Generate Human Behaviors 2. Making Machine Learning Applications for Time-Series Sensor Data Graphical and Interactive. 3. Usability evaluation of smart watch UI/UX using experience sampling method 4. Multi-modal Interruptions in a Context Based Framework **Other publications, conference papers and presentations:** 1. Improving User Experience in Ubiquitous HCI Situations - Sensors Know When to, How to, and What to Interact with Human, Hanyang University, 12/20/2016 2. Improving User Experience in
Ubiquitous HCI Situations - Sensors Know When to, How to, and What to Interact with Human, GIST, 04/18/2017.

**Anticipated Research Outcomes:**
- Presents an example system that helps drivers become aware of and understand their aggressive driving behaviors
- Presents a prototype machine learning (ML) and visual analytic system that leverages ML applications for sensor-based time-series data collected during naturalistic driving tasks
- Presents study results in a human-subject based field-driving experiment that incorporates sensor-based technologies to predict expected duration of drivers’ in-situ interruptibility during naturalistic driving contexts.

**Anticipated Impacts:**
- Will leverage the development of a working prototype that incorporates sensor-based technologies to assess real-time cognitive load, driver interruptibility and driver experience
- Expected to address the issues of ubiquitous HCI in cars and the intelligibility of system behavior in naturalistic field driving situations
- Expected research outcomes to be scalable to other application domains where computational aids proactively support users’ in-situ decision-making in situations of high uncertainty that include a potential cost of additional perception or cognition.

**Did research results confirm or change practice?:**
Confirmed until now.

**Web Links:**
- UTC websites - Sensor-based Assessment of the In-Situ Quality of Human-Computer Interaction in the Cars (2016, active; http://utc.ices.cmu.edu/utc/projectitem.asp?ID=194)
- UTC publication - http://www.cs.cmu.edu/~sjunikim/utc_works/utc_publications.html
- Other websites of the research team
  * PI and Co-PI research areas and details: Dr. SeungJun Kim (http://www.cs.cmu.edu/~sjunikim/) / Prof. Anind K. Dey (http://www.cs.cmu.edu/~anind/)
  * Project websites: Human-Vehicle Interaction (http://ubicomplab.org/project/human-vehicle-interaction-2/) / Multisensory Augmentation (http://ubicomplab.org/project/multisensory-augmentation/)

**Issues:**
Change PI: Sooner or later, we’ll want to request to change PI from Dr. SeungJun Kim (the current PI of this project) to Prof. Anind K. Day (the current Co-PI of this project).

Dr. Kim received an offer of a regular faculty position from a university in Korea, so his current CMU position (Systems Scientist at HCII) is supposed to end in May or earlier, 2017. His new position for CMU will be an adjunct faculty member from June, 2017.

**Accomplishments:**
- Published or submitted 4 papers or more, and gave a series of invited talks as other dissemination activities
- Completed setting ups a simulated driving test-bed that includes an open driving simulator, VR headsets, an eye tracker, and other sensor devices to monitor driver states in real time
- Prototyped initial versions of visual analytic systems for driver behavior assessment and relevant ML applications

**Co-design of Computation and Control Algorithms for Low-Cost and Low-Power Autonomous Vehicles, PI:** Aaron Steinfeld **Co-PI(s):** Anthony Tomasic, John Zimmerman

**Deployment Partners:** Port Authority of Allegheny County, Tiramisu Transit LLC


**Anticipated Research Outcomes:** We developed semi-autonomous methods for detecting connections in travel trace data. We labelled 3205 trip pairs from the Tiramisu Transit app to find and analyze 341 connections traced from 142 devices by Pittsburgh transit riders in 2012-2013. From this, we found that 79.4% of the users' connection distances were within 0.25 miles (straight-line) and 44.9% of the connections were less than 10 minutes.

We then identified highly utilized transfer locations, including many that are not designated by the Port Authority of Allegheny County as recommended transfer stops in the GTFS. For example, we detected many connections in Oakland along the Forbes-Fifth corridor while most of the recommended transfer stops are in the Downtown core.

This data was also mapped to the City of Pittsburgh violent crime data, which showed some highly utilized transfer locations within regions with elevated crime rates.

**Anticipated Impacts:**
We believe the algorithmic detectors of connections and the associated metrics of connection quality have value. These approaches will undergo detailed peer review in the near future.

**Did research results confirm or change practice?:**
Too early to determine if the project findings will impact service approaches in public transportation.

**Web Links:** None

**Issues:** While many trip trace behaviors can be used to help automatically detect transit connections, we found that some human labelling was still required. There are certain tracing actions that are hard to quantify using current data.

**Accomplishments:** This work was accepted by peer review for a poster presentation at the 2017 TRB Annual Meeting. A journal article on this work is in preparation and will be submitted during 2017.

**Stereoscopic Programmable Automotive Headlights for Improved Safety Road, PI:** Narasimhan Srinivasa, **Co-PI:** Robert Tamburo, **Students:** Srihari Sankar, **Presentations:** In
2016, we gave the following live demonstrations of the research to the following: Visitors from ITSPA, Visitors from FLIR, CEO of Foxconn, Chief engineer and design, optics, headlight people from Ford, Representatives from PennDOT District 11, NREC 20th Anniversary Open House, Visitors from PennDOT, Traffic21 T-SET Advisory Council, General Pawlikowski and other Air Force servicemen and SEI group at NREC, Honda America group, NSF CPS PI Meeting, Iron City Micro-mirror Display, and NGK. We also gave presentations to Ford Motor Company, General Motors, and UTC T-SET Symposium. In 2017, we have continued to give demonstrations and presentations: Iron City Micro-mirror Display, NGK, government employees from Dubai, Mahindra & Mahindra, Smart Belt Coalition, Pittsburgh Inclusive Innovation Week, Night at NREC (graduating students), and Women in Transportation.

**Anticipated Research Outcomes:** We have two programmable headlight prototypes installed in a vehicle. Our FPGA/ARM PCB baseboard (for the embedded platform) has been re-designed to be more computationally efficient, more electrically stable, and rugged for handling driving conditions. We have compiled a linux kernel for reliably (no packet loss) transferring data between the two headlights at near practical gigabit ethernet speeds. An FPGA pipeline has been developed to swap in/out basic image processing IPs to either build more complex processing streams or to schedule a task based on demand requirements. A DMA engine has been written to transfer data between FPGA memory and the ARM processor. A depth estimation IP has been developed that estimates the depth of objects from rectified images. We are working on methods to combine data streams from the FPGA/ARM and a personal computer to create a heterogenous computing platform to address a wide array of computationally intensive algorithms/tasks. As we polish our stereo headlight system, we expect a research platform for developing new and exciting algorithms for improving road safety, and for road testing those new methods.

**Anticipated Impacts:** We are in frequent communication with stakeholders in the auto-industry. They have expressed interest in the system. Integration with vehicles on the market could have a significant impact on improving safety. There is no other headlight like it on the market.

**Did research results confirm or change practice?:** Research results not yet released.

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

**Issues:** N/A


**Weblinks:** http://www.sciencedirect.com/science/article/pii/S0968090X16301590

**Accomplishments:** December 2016 Elsevier Atlas Award: “Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions” published in the journal Transportation Research Part C: Emerging Technologies has been selected from thousands of recently published articles to be awarded the Elsevier Atlas. Each month a single Atlas article is selected from published research from across Elsevier’s 1,800 journals by an external advisory board made up of individuals from NGOs including the following organizations, among several others.

**The built environment and pedestrian safety in the Philadelphia region, PI:** Erick Guerra  
**Co-PI(s):** Michelle Kondo & Chris Morrison, **Deployment Partners:** Delaware Valley Regional Planning Commission, Philadelphia Streets Department, Penn Industry Science Center  

**Anticipated Research Outcomes:** We have completed the analysis of the effect of Penn’s policing catchment area on collisions. We conducted regression discontinuity analysis and t-test on selected streets to examine the effect of police presence on the number of crashes at intersections. The number of crashes is aggregated for the nearest intersections on either side of Penn Police’s patrol area boundaries. Limited by the small number of intersections in the sample, we did not find consistent results across these analyses. More generally, we did not find a relationship between enforcement and collisions. This overall null finding is complicated, however, because of the small sample and the fact that greater policing tends to increase the percentage of collisions that are reported (particularly for pedestrian collisions). We have written up the analysis, but will not be pursuing this aspect of the study further.

Preliminary analysis of the relationship between neighborhood density and pedestrian and vehicle collisions has been more promising. Looking across neighborhoods in the Philadelphia region and within neighborhoods over time, we are finding that higher densities are associated with lower collision rates and, at least cross-sectionally, fewer collisions. To examine changes over time and place, we created a panel by matching four years of crash data from the Philadelphia region to four years of ACS and economic data at the Census Tract level, as well as cross-sectional data about land use, road conditions, and traffic volumes. The Philadelphia region has substantial variation in built form, collision rates, and the socioeconomic composition of neighborhoods. While fatality rates are lower than the nation’s and Pennsylvania’s, they are
comparable to cities like Los Angeles and Seattle. We are still in the process of collecting and processing data about road networks and matching these to collisions and Census Tracts.

The next phase of the analysis will focus on how differing units of analysis (road segments, intersections, census tracts, grid cells, etc.) and measures of exposure (pedestrian mode share, traffic volumes, population density, etc.) influence findings about the relationship between the built environment and collisions. The geospatial matching of data is ongoing.

**Anticipated Impacts:** Findings from this study will contribute to understanding of the relationship between population density and traffic collisions, and to policy discussions about the relative benefits of using local planning powers to allow or prevent marginal increases in development.

The next phase of the analysis will help researchers and practitioners make better informed decisions about the correct unit of analysis and the best exposure controls when examining the relationship between the built environment and collisions across space.

**Did research results confirm or change practice?:** The research is in progress and it is too early to determine.

**Weblink:** [http://crashphilly.erickguerra.net/](http://crashphilly.erickguerra.net/)

**Issues:** Nothing to report

**Accomplishments:** Preliminary findings were used in the descriptive sections of a coauthored book with Robert Cervero (UC Berkeley) and Stefan Al (UPenn).

**Anticipated Research Outcomes:** 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.

**Anticipated Impacts 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.