Program Progress Performance Report
for University Transportation Centers

Agency: US DOT
Office of the Assistant Secretary for Research and Technology
UTC Program

Federal Grant Number: DTRT-13G-UTC-26
Project Title: Technologies for Safe and Efficient Transportation (T-SET)
Tier 1 University Transportation Center

Program Director: Dr. Raj Rajkumar
raj@ece.cmu.edu
412-268-8707

Submission Date: July 30, 2015
DUNS Number: 05-218-4116
EIN Number: 25-0969449
Recipient Organization: Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213

Recipient ID Number: 27484.x.1080266
Project Grant Period: 1/31/2014 – 9/30/2017
Reporting Period End Date: June 30, 2015
Report Term or Frequency: Semi-Annual

Signature: [Signature]
1. Accomplishments

Major Goals and Objectives of the Program

Research, Development and Deployment by the T-SET UTC

The CMU-Penn T-SET UTC focuses on research, development and ultimately deployment of technologies for safe and efficient transportation. 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. Each of the 16 research projects has identified Year 1 and Year 2 Desired Outcomes and Metrics.

Metrics
- Number of publications and citations of faculty work in transportation-related areas.
- Number of new hires, new research initiatives, and special projects that build on intellectual leadership in fields related to the mission of the UTC.
- Research collaborations in related fields.
- Quantified impact of technology deployments and transfers.

Education and Workforce Development

Education and workforce development are important compliments of the T-SET research program.

Metrics
- Number of institutional educational partnerships
- Number of participants in workforce and educational programs
- Number of related degrees awarded at our institutions
- Number of new educational programs established
- Number of job placements through workforce development programs.

Technology Transfer

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

Metrics
- Involvement of faculty in technology transfer activities.
  - Number of conferences, meetings, and formal discussions that focus on end users of ITS
  - Number of patent applications filed
  - Number of startups created
  - Number of technology licenses issued

Collaboration

Collaboration is the heart of the entire T-SET program. Carnegie Mellon and the University of Pennsylvania seek to ensure our research and development program leads to deployment of technologies in the transportation systems serving our communities and state, providing pilots 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, educational partners and industry partners.

Metrics
- Number and diversity of members of the T-SET Consortium
- Number and impact of deployments achieved through collaboration

Diversity

T-SET projects will focus on transportation users in both rural areas and center cities, in suburban commuters and on residents of small communities with limited transportation options.

Metrics
- Participation by students and faculty of color and women in UTC research projects
- Projects focused on rural, city, and suburban residents
- Number of projects targeted at aging populations and persons with disabilities
Accomplishments Under the Major Goals

See Appendix A for specific research project accomplishments

MAJOR ACTIVITIES

This period of performance for T-SET was exceptionally active. Secretary Foxx came to speak on CMU’s campus as part of USDOT’s “Beyond Traffic Initiative” in April. Assistant Secretary Greg Winfree keynoted the first UTC Safety Summit held by CMU on March 19 and 20th, with 65 participants including 14 UTCs and national representatives from government, industry and community groups.

In May, ITS America held its Annual Meeting in Pittsburgh, T-SET was a major sponsor of the conference and T-SET was involved in the host committee, paper reviews, the expo, presenting and moderating sessions and sat on keynote panels. T-SET also hosted an Autonomous Vehicle Demonstration, Adapted Signal and Connected Vehicle Test Bed technical tour at the ITS America Annual meeting. In addition, T-SET had live feeds of connected vehicles driving through our connected vehicle test bed in Pittsburgh live fed to USDOT’s expo booth at the conference.

CMU also hosted ASCE and Building America’s Future Event “Pittsburgh on the Move” featuring former Governor, Edward Rendell on May 13th. T-SET also hosted the PA House of Representatives Transportation Committee for a series of presentations on research and technical tours on June 12th. It is also noteworthy that CMU has been in negotiations with the Pennsylvania Turnpike Commission for an intergovernmental agreement during the spring of 2015.

Education and Workforce Development

Below is a listing of specific additional Education and Workforce Development efforts T-SET personnel have engaged in over the past six months:

- Created the Women in Transportation Scholarship for the Robotics Institutes Summer Scholar Program.
- Growth with Intelligent Transportation Systems, Profs. S. Qian and S. Caldwell.
- Faculty Seminar Series presented T-SET research to student body at two lectures:
  - Connected Vehicle Vision 2040, Al Biehler and Chris Hendrickson
  - Connected Vehicle Test Bed, Stan Caldwell and Zack Rubenstein
- Attended Young Professionals in Transportation Pittsburgh Chapter Meeting
- Attended Transit Geeks Pittsburgh Meeting
- Placed a graduate student in PennDOT's GIS department
- Sponsored Transportation Club Happy Hour
- Revised Pennsylvania Governor's School Intelligent Transportation Class for Summer 2015
- Developed Challenge Activity in collaboration with Rutgers University for Women's Transportation Seminar Transportation YOU Summit in Washington, DC
- Attended and facilitated at Transportation YOU Summit in Washington, DC
- Reviewed papers for ITSA Annual Meeting
- Attended STIC Innovation Day
- Hosted two T-SET faculty meetings
- Hosted a faculty meeting to discuss transportation energy at CMU

Technology Transfer and Collaboration

In partnership with the Traffic21 Institute and the Center for Innovation and Entrepreneurship at CMU, T-SET has developed an Entrepreneur in Residence program to enhance it's technology transfer efforts.

- Keynote speaker at State Transportation Innovation Council Regional Meeting
Hosted the following:
UTC National Safety Summit
ITSA Annual Meeting
ITSA Technical Tour of Autonomous Vehicle
ASCE Building America’s Future Event
Pittsburgh Urban Magnet Project (young professional group)
A visit to CMU by City of Pittsburgh Directors of Planning, Public Works and Innovation and Performance
A visit to CMU by Vinn White and USDOT Staff
A visit to CMU by Katie Turnbull from TTI
A Visit to CMU by Santiago Garces, Chief Innovation officer for the city of South Bend

Presented at the following:
PA Utilities Summit
Pennsylvania Coalition of Transportation Universities
Research Workshop with PennDOT and FHWA
AAMVA National Meeting
RETC Fly In
Monthly meeting of American Council of Engineering Companies
Southwestern PA Commission’s Transit Operator Meeting
NACO Engineers Event
National Economic Council - Build America
Smart Infrastructure Institute Symposium

Participated in the following:
ITSA Leadership Circle Meeting
Envision Downtown Pittsburgh Committee Meeting
Office of Science and Technology Policy of the White House University and City Event
Vehicle to Infrastructure Development Coalition Workshop
National Bike Summit
Women’s + Bike Summit
Mobility Lab’s Transportation Camp DC
City of Pittsburgh P4 Conference
NSF Big Data Hub Event
Great Lakes ITE Conference
PennDOT Universities Symposium
Mayor Peduto Innovation Roadmap Event
WTS Annual Meeting
Fuel Freedoms Trustees Meeting
NIST Tech Jam
NACO
Heinz Alumni Meeting
Bella Dinh-Zarr Swearing In
Joint Pittsburgh and Philadelphia Chambers of Commerce Public Officials Reception
Congressman Keith Rothfus Transportation Roundtable

Local Government Academy Visit to CMU
A visit to CMU by Steve Koonan of CUSP
A visit to CMU by the PA House Transportation Committee
Demonstration of Downtown Simulation of Traffic Signals
City of Pittsburgh Department of Public Works meetings with CMU faculty
Meeting with ITS America Annual Meeting Media Team
Public Policy and International Affairs Fellows for a lab visit
Visitors from Equus Research Co., Ltd.

Pittsburgh Urban Magnet Project (young professional group)
Pittsburgh Mayor Peduto Innovation Session
Pennsylvania State Transportation Innovation Council Meeting
Southwestern PA Commission Operations and Safety Committee Meeting
UTC Winter Meeting
CUTC Winter Meeting
TRB Annual Meeting
ITS American Reception
PA Governor Wolf Inauguration
Interview with Amanda Waltz from Pop City Media
City of Pittsburgh recruiting event for Heinz College Students
Regional Open Data Portal RFI Review Committee
US DOT ITS JPO Affiliated Test Bed Monthly Meeting
Heinz College Systems Amtrak Synthesis Advisory Board Meeting
Industrial Internet Consortium
CMU SITE i-corps meeting
Building a Better Busway
Held meetings with the following:

Indian Railways Executives
The Benedum Foundation
Chief Innovation Officer of Pittsburgh, Deb Lam, DPW Director Guy Costa and Director of City Planning, Ray Castil
Capitol Hill Meetings with Members of Congress to Discuss UTC Research
Delegation of Swedish Transportation Leaders
Meeting and Tour at the Community College of Allegheny County Automotive Center
Meeting with Caryn Moore from the House Transportation Committee
LTV SSW Hot Metal Intersection Meeting with URA to discuss adaptive traffic signals
Meeting with Debra Lam, City of Pittsburgh Chief of Innovation
Meeting with Merrill Stable, CEO of Alco Parking
Meeting with Sara Morgan from Delta Development
Meeting with Intel
Butler Transit Authority
PIT Airport CEO, Christine Castos
U.S. Government Accountability Office
Uber Government Affairs
TomTom

Diversity
• Started The Women in Transportation Scholarship for the Robotics Institute Summer Scholars program, placing an undergraduate women in a robotics lab focused on transportation research for the summer. This program gives students unparalleled experience in research.
• Selected the Women in Transportation Fellow at the Heinz College for 2015-2017 cycle.
• Collaborated with Rutgers University to design Challenge Activity for the WTS Transportation You Summit in Washington, DC.
• Facilitated and mentored at the WTS Transportation You Summit in Washington, DC.
• Dana Peck, CMU EPP '15, was awarded UTC Student of the Year.

2. Products

See Appendix A for specific research project products including publications, technologies, and inventions.

General Program Products
• Weekly distribution of research news articles and T-SET promotions in weekly newsletter (1,236 subscribers)
• Presence on social media: T-SET more than doubled our Twitter following, increasing from 240 to 506 followers, and have a total of 2,608 tweets.

T-SET in the Media

Efforts have been made to promote T-SET UTC activities though the media. Below are some examples of T-SET media exposure from January – June 2015. Click on the hyperlink to view articles:

Articles:
Raj Rajkumar at CMU: Leading the Way for Autonomous Cars (India Times)
6 questions for Carnegie Mellon autonomous car prof Rajkumar (AP)
This almost-but-not-quite-driverless car is smarter than your car (Washington Post)
Will Self Driving Cars Spell the End of the Road Trip (SLATE)? First driverless car trials in Southern Hemisphere to be held in Adelaide, coinciding with international conference (ABCNews)
Welcome to Pittsburgh, ITS. Welcome to the future, America (IIT Fastlane)
Bright Green Autopods The Newest Way To Get Around Downtown (CBS Pittsburgh)
Carnegie Mellon Researchers Find Charging Electric Vehicles At Night is DIRTY (Traffic21Blog)
Electric Cars Can Explain Our Highway Funding Fiasco (Traffic21Blog)
Car headlights of the future won't blind other drivers (Engadget)
DOT secretary 'bullish' on CMU transportation technology (Pittsburgh Business Times)
Transportation chief visits Pittsburgh to view new research, technology (Pittsburgh Post-Gazette)
During Pittsburgh visit, transportation chief says infrastructure should 'outrage' Americans (Pittsburgh Post-Gazette)
Band-Aid approach to infrastructure can't continue, U.S. transportation chief says in Pittsburgh (TribLIVE)
Driving toward the future
Pittsburgh is helping to create the next generation of life-saving traffic technology (Pittsburgh Post-Gazette)
Transportation group meets here this week (Pittsburgh Post-Gazette)
CMU, Pittsburgh's Surtrac program aims to ease traffic congestion (Tribune Review)
A Robot to Help Visually Impaired Passengers Navigate Public Transit (Citylab)

Driven from distraction (The Economist)
'Smart' parking arrives in Dormont (Pittsburgh Post-Gazette)
PennDOT prepares for 'cars of the future' (FOX43 News)
Peek fender-bender: Technology can prevent car crashes, if consumers will buy in (Washington Post)
Ford drives scheduling with artificial intelligence (ComputerWorld)
On the road to innovation: How Pittsburgh is helping to change state transportation (POP City)
Self-driving car wish list: Safety but not coffee (ABC News)
Study: Most drivers see safety benefits of self-driving cars
What this 'Impact' Specialist says about Autonomous Transportation (Driverless Transportation)
Looking Into The Future On Electric Vehicle Adoption (Roll Call)
Traffic lights on your windshield could get you home faster (CNN International)
7 Ways Self-Driving Cars Could Impact States and Localities (Governing the States and Localities)
Automakers on the road to self-driving cars at Consumer Electronics Show (L.A Times)

3. Participants and Other Collaborating Organizations
We continue to grow our Consortium and now have over 50 organizations from public organizations, government and industry. We plan to hold an advisory board meeting and a consortium meeting this fall.
Vehicle Automation Technologies

BUMPER-TO-BUMPER: A VISION-BASED SYSTEM FOR HIGH EFFICIENCY VEHICLE PLATOONS IN METROPOLITAN AREAS, SRINIVAS NARISIMHAN, CMU

Participant Organizations: Financial support by grant from the National Science Foundation and a gift by Ford Motor Company.

Other Collaborators: James Hoe in the Department of Electrical and Computer Engineering at CMU.

Task List: The goal of the project is to develop a high-speed, hardware and software computer vision that can track vehicles and estimate their relative speed and distance. Fast estimations would permit vehicles to closely follow each other in platoons.

- We have begun to conduct traffic simulations to demonstrate the benefit of the technology on traffic congestion, environment, and commute times in urban areas.
- We are close to completing the system's hardware design, which is an embedded solution via an FPGA.
- We have begun to develop a software pipeline architecture for optimal data throughput and processing.
- We have implemented a tracking algorithm on an FPGA board (Xilinx Zynq).

CONNECTED TECHNOLOGY FOR IMPROVING CYCLING SAFETY, ANTHONY ROWE, CMU

Technologies / Techniques: We have created a data collection platform (figures attached) that allows us to evaluate multiple different ranging technologies between cars and cyclists as well as inertial-based trajectory prediction of cyclists.

Impact: Nothing to report (yet). We soon hope to have a sensitivity analysis of various cycle-specific estimation techniques.

Task List: Task 1: Build Data Collection Platform (not quite 100% but useable)
Task 2: Data collection (1st round of ground-truth data collected in parking lot scenario)
Task 3: Cyclist Trajectory Model (underway)
Task 4: Real-Time Alerting (Fall 2015)

Infrastructure Technology

INFRASTRUCTURE MONITORING FROM AN IN-SERVICE LIGHT RAIL VEHICLE, JACOBO BIELAK, CMU

Journal publications: Note that our collaborators Kovacevic and Chen's work in Graph Signal Processing addresses some of the challenges we found together in vehicle-based monitoring. They received some of the funding from this project in the past and these published work acknowledges this UTC support.


Other publications, conference papers and presentations:

Other Dissemination Activities:
-Presentation at the Smart Transportation Technology Showcase, June 12th, 2015
-Attending the booth at the ITS Annual Meeting on behalf of T-SET; discussed current research with attendees
-Podcast on CMU website about sensors (https://soundcloud.com/cmu-engineering/sensors-the-new-macro-scale)
-Webinar on our research for PSII on Feb 6th, entitled “A Usable Infrastructure Diagnostic Tool and Its Deployment on Pittsburgh’s Light Rail Line”

Technologies / Techniques: We have continued to develop graph signal processing as an efficient and elegant technique to analyze large data sets with complex structure. In addition, we have instrumented a second train with the Port Authority of Allegheny County, thereby improving our data collection process. This semester we have built on the work previously identifying changes in the rail network. We have conducted simulations to explain why our previous techniques work well.

Invention / Patent applications / Licenses: We have applied for a provisional patent entitled, “A System to Enable Rail Infrastructure Monitoring Through the Dynamic Response of a Passing Train.”

Other Products associated: Databases. We have been building a substantial database with the information we have collected from the Port Authority.

Impact: We are developing a technology which could drastically reduce the cost of collecting objective information on state of a rail network. This could increase rail safety and allow for more targeted maintenance. By placing low-cost sensor on operational trains, entire networks can be continually monitored with a few cars. We are researching fundamental analysis techniques, as well as applied methods to overcome practical challenges. This reporting period, we have advanced our theoretical understanding of signal processing for infrastructure assessment, collected more data from operational trains, and gained a better understand of the underlying behavior of our data. Much of our focus has been on simulating the behavior of the train to understand why certain machine learning features lead to high classification accuracy. We have found the real data to be complicated to analyze, however we now understand which sources of uncertainty are the most difficult to handle, and we are working towards minimizing these sources of uncertainty.

We have been collecting data from a vehicle on the light rail system with hopes of monitoring the track and track structures. One of the challenges in working with this signal is that each day the temperature, speed, and weather conditions might be slightly different; before looking for damage, we have to understand which parts of the signal change in a benign way due to environmental variability. We believe that graphs for signal processing may offer a promising route; each signal can be viewed as a node, and the similarities between them can be represented as edges. An anomalous signal will then be one which exhibits strange behavior for its particular location within the graph.

If our work is successful, we hope to create an economical infrastructure assessment tool which can mounted on in-service vehicles. In addition, this project has helped to prepare the next generation of scientists who can draw on advances in signal processing and machine learning to make infrastructure assessment more efficient.

Impact in other disciplines: The signal processing techniques researched under this grant were recently presented at a prominent signal processing conference (ICASSP), and will be published in IEEE transactions in Signal Processing, one the premier journals in the field. Signal processing within the civil engineering discipline is a nascent field. We are both applying proven techniques from signal processing to Structural Health Monitoring, as well as developing processing techniques which are novel even within the signal processing community.

Task List: Conduct field experiments in a semi-controlled environment (Ongoing)
Build a model of baseline response of the Port Authority Light Rail System (Ongoing)
Determine ability to reliably detect changes in the track and track structure (Ongoing)
Develops new tools for analyzing the dynamic response of train, taking into consideration the observed sources of uncertainty. (Ongoing)
INFRASTRUCTURE MONITORING, CHRISTOPH MERTZ, CMU
http://www.ri.cmu.edu/person.html?person_id=670

Participant Organizations: City of Pittsburgh - pilot testing our system
Marshall Township - pilot testing our system

Other Collaborators: Andrew Fox, master student at ECE - he uses a subset of our data to investigate how
acceleration, gyro, and GPS data can be used to determine road quality.
Ahmed Fahmed, Temple University - we started to collaborate in using the road monitoring system for his
pavement research.

Other publications, conference papers and presentations:
Presented project in computer vision class
Presented project to officials of City of Pittsburgh
Presented project to PA representatives, members of the transportation committee
Presented project to Secretary of Transportation Anthony Foxx
Presented project to delegation from automotive company
Interviewed by Pittsburgh's NPR News Station

Technologies / Techniques: We have initial computer vision algorithms implemented in Matlab code to detect
and assess stop signs. We have scripts that run these algorithms on our collected data and display the results on a
map.

Other Products associated: Databases; Software / Netware. We continue to collect data of the road
infrastructure in Pittsburgh, Marshall township and surrounding areas.

Impact: Within the discipline of Robotics and computer vision: Expand the field to include transportation
research, expose students to transportation research. On the reverse, computer vision is being introduced into the
field of transportation and maintenance. The direct practical impact is that government agencies (specifically
City of Pittsburgh and Marshall township) can use our technology to improve their infrastructure maintenance by
having up-to-date and accurate information available about the state of the infrastructure.

Task List: Initial research - started
Software - first version ready
Implementation - first version of software implemented

PEDESTRIAN FRIENDLY TRAFFIC SIGNAL CONTROL, STEPHEN F. SMITH, CMU

Participant Organizations: CitiLog, Inc., GridSmart, Inc.

Other Dissemination Activities: Hosted bus tour of Surtrac adaptive signal deployment site at ITS America's
annual meeting in Pittsburgh on June 1, 2015. Surtrac incorporates several mechanisms for giving active attention
to pedestrians (in response to pedestrian push button calls).

Task List:
1. Pedestrian density detection [4 mos.] - Using the XCAM-ng as an initial hardware platform, we will develop
algorithms that exploit detection information from multiple pre-defined presence detection zones to learn a model
for predicting pedestrian density.
2. Pedestrian presence and density detection in the radar setting [4 mos.] - We will first explore potential for basic
pedestrian presence detection capability for the Wavetronix matrix sensor (expected to be successful to some
extent) and then attempt to transfer the pedestrian density detection algorithm(s) developed in Task 1 to this
setting (expected to be a more difficult challenge).
3. Use of direct pedestrian-to-infrastructure communication [4 mos.] - We will develop extensions to the current
Surtrac intersection scheduling procedure to appropriately increase pedestrian crossing times and support the use
of a "handicapped pedestrian app". For proof of principle testing (and extension to other potential apps) we will
develop a smart phone app for communicating with Surtrac (through the DSRC receivers to be installed along the
Baum-Centre corridors if possible).
4. Field-testing and evaluation [4 mos.] - We will evaluate the effectiveness of each of the above mentioned
technology results through independent pilot tests within the Surtrac test bed deployment. XCAM-ng capability
will necessarily be evaluated at one strategic intersection crossing (since we only have access to one sensor).
Field-testing of the Wavetronix capability will proceed initially at one intersection and if successful will be incrementally expanded (extending to full deployment along Baum-Centre corridors in the best case). Pedestrian to Infrastructure capability will be tested at a single intersection.

**In-Vehicle Technology**

**AUTOMATED DETECTION OF OBJECTS IN REAR CAMERA IMAGES, VIJAYAKUMAR BHAGAVATULA, PENN**

**Other Collaborators**: Dr. Shayok Chakraborty

**Techniques**: At present, we are using background subtraction algorithms (using Gaussian Mixture Models) to learn a robust background model in order to detect the presence of objects (foreground), which do not fit the background description. We are also using a ground surface classification technique (based on pyramid on HOG features and SVM classifier) to classify ground and object pixels. The predictions using the two algorithms are combined through a fusion framework for robust object detection. Our first set of experiments, using this framework, has demonstrated encouraging results.

**Impact**: A system which can robustly detect the presence of objects in rear-camera images has tremendous potential in reducing the number of backover accidents.

**Impact in other disciplines**: The proposed framework can be viewed as a generic object detection system. It can also be used in several other applications including security and surveillance to detect abandoned or removed objects in airports and other public places.

**Task List**: In order to improve the accuracy and the speed of the automated object detection methods for rear-camera images, we plan to investigate the following research topics:

1. Expand the image database by collecting more images at different locations and weather conditions. We will make the dataset and the annotations publicly available to facilitate further research in this topic.

2. The proposed method is developed to detect objects of arbitrary shapes and sizes behind the parked car. We plan to augment our framework to detect the presence of children in particular, so that an alarm can be triggered to alert the drivers. A possible solution is to use a skin color detection algorithm to detect skin colored pixels within the segmented regions. This will be taken up as part of future research.

3. Analysis of our results revealed the fact that most of the pixel-level errors are caused by illumination changes. As part of our future work, we plan to address the effect of illumination in detecting objects. We intend to exploit existing research on shadow removal for this purpose.

4. An interesting direction of future research is to predict the posture of the children (sitting/standing/lying) and its distance from the rear end of the car, besides predicting merely its presence. We plan to take this up as part of our future work.

**SENSOR-BASED ASSESSMENT OF THE IN-SITU QUALITY OF HUMAN-COMPUTER INTERACTION IN THE CARS, SUENGJUN KIM, CMU**


**Participant Organizations**: Two academic institutions (CMU & UNIST), one international research institute (KETI), and one school of driving in the local area (Cindy Cohen School of Driving)

• CMU, Human-Computer Interaction Institute (HCII), Ubiquitous Computing Lab (director: Prof. Anind K. Dey, co-PI of this T-SET UTC project; special faculty member: Dr. Seungjun Kim, PI of this project)

**Other Collaborators**: Prof. Anind K. Dey (co-PI), Dr. Jaemin Chun, and Dr. Sunyoung Cho (CMU, HCII, UbiComp Lab)

• Dr. KyungTaek Lee (KETI, Contents Convergence Research Center, South Korea)

• Prof. Ian Oakley (UNIST, Interactions Lab, South Korea)

• Several visiting scholars, undergraduate research assistants, and international interns

**Journal publications**


Other publications, conference papers and presentations:

- Three conference papers
  - Published
  - Published at the top-tier conference of HCI field + Presented at Seoul, South Korea (http://chi2015.acm.org/)
  - Ready to re-submit

Other Dissemination Activities:

- “Road safety. Driven from distraction - How to save phone-using from themselves”, The Economist, Science and technology, 25 Apr 2015 (by Paul Marks)

Technologies / Techniques:

- In-car sensor fusion technology (focus: tracking real-time driver and driving states and sensor data mining techniques for the assessment of driver experience in near real-time)
- Visual-analytic tool development technology (focus: time-series sensor data) – proven by a set of more than two probe-based studies with our prototype machine learning and visual analytics system
- Modality fusion and sensory augmentation technology, by incorporating augmented reality and haptics technology

Invention / Patent applications / Licenses:

- Invention disclosure

Other Products associated: Audio / Video; Databases; Data & Research Material; Physical Collections; Software / Network

Impact:

- Has a significant impact upon user experience associated with dual-task paradigm and immersive situation awareness (at the intersection of ubiquitous computing, human-computer interaction, and machine learning)
  - Example - The two papers obtained through this project (i.e., driver interruptibility at CHI conference + cognitive distance and in-situ cost & value of context-sensitive information for MTAP journal) contributed to leading a new funding project for the research team (Topic: “Immersive Situation Awareness” with Draper Laboratory – Innovations in engineering)

Task List:

- Task 1 – Paper submission and publications (80% done)
- Task 2 – Generating follow-up study items and new research projects (80% done)
- Task 3 – Prototyping visual-analytic tool for time-series sensor data streams (90% done)
- Task 4 – Launching a survey study on wearable UI/UX for automotive domain (with KETI, 40% done)
- Task 5 – Building a conceptual framework (10% done)
- Task 6 – Prototyping hardware/software modules for the next field study (investigating real-world impacts of interruptions upon drivers through the use of an Android GPS with the help of several interns and research assistants, 20% done)

DRIVER STATUS MONITORING IN AUTONOMOUS VEHICLES USING IN-SEAT INERTIAL SENSORS, HAE YOUNG NOH, PEI ZHANG, CMU

Other Dissemination Activities: informal talks for the CEO of Renault and Nissan, board of directors, as well as significant research leads for the two companies.

Technologies / Techniques:

- 10 March 2015 – PI presented project scope and ideas to Deborah Lam (Chief Innovation Officer of the City of Pittsburgh) and Grant Erwin (Sustainability Manager for the City of Pittsburgh) as part of set of presentations organized by Rick Stafford, and received helpful feedback from stakeholders.
Other Products associated: Instruments or equipment. We have developed vibrational hardware that can measure multi-point vibration from the car seats at 200Hz when all 20 sensors are active.

Impact: The outcome of our research will include a hardware that consists of the sensor node, aggregator, and backend server to infer driver’s physiological states in a car setting. This system will include both the hardware and software algorithms to determine and classify the features of the person’s macro-motions (posture and motion) and micro-motions (muscular and cardiovascular activities), which helps the autonomous car with understanding the driver’s states, such as attention level, fatigue, and stress. The system will also include algorithms that separate the driving noise of the car and road.

Task List:
1. (Completed 1st version) Develop hardware to capture vibration data in car seat using multiple vibration sensors
2. (Complete) Collect initial data in a normal seat to capture signals of breathing and heart beat
3. (In progress) Develop visualization software to visualize multiple vibration sensor data
4. (In progress) Develop preliminary algorithm to detect breathing and heart beats
5. Optimize sensor placement within the seat and incorporate the sensing platform into seats
6. Collect data in moving vehicle
7. Develop noise reduction algorithms.
8. Evaluate physiological extraction in moving vehicle in different driving conditions

IN-VEHICLE VISION-BASED CELL PHONE DETECTION, BERNARDO PIRES, CMU
http://www.contrib.andrew.cmu.edu/~bpires/phonedetect.html

Other Collaborators: Jian Gong
Christopher Kaffine

Technologies / Techniques: Equipment has been purchased and illustrative data collection has been done. Novel video annotation tool is under development.
(See PPT attachment)

Impact: Current research is likely to make an impact in the computer vision field in two ways:
1. The novel annotation tool developed on this and the pedestrian detection project will greatly facilitate the annotation of large video datasets;
2. We expect to make significant contribution to specific hand-held object detection under constrained environments

Impact in other disciplines: We expect to make a significant contribution to the automotive safety field by detecting the active manipulation of electronic devices by the driver. This is often the most dangerous driver behavior and the one that leads to many of the distracted-driver accidents.

Task List: Selection and purchase of equipment - Completed
Review of methods in the literature - Completed
Development of data labeling tool (shared with pedestrian detection project) - Ongoing
Collection of over-the-shoulder view dataset - June 2015
Labeling and preparation of dataset - September 2015
Training and testing of cell phone detector - December 2015

OPTIMIZING SNOW PLOWING OPERATIONS IN URBAN ROAD NETWORKS, STEVE SMITH, CMU

Participant Organizations: City of Pittsburgh Public Works Department

Other Collaborators: TeMeDa LLC

Other publications, conference papers and presentations:

Technologies / Techniques: Prototype in-vehicle mobile application for conveying, turn-by-turn routing instructions to snow plow drivers.
SENSORY AUGMENTATION FOR INCREASED AWARENESS OF DRIVING ENVIRONMENT, 
JOHN DOLAN, CMU
http://www.ri.cmu.edu/research_project_detail.html?project_id=651&menu_id=261

Other publications, conference papers and presentations:

Other Dissemination Activities:
Submitted the following paper to ICRA 2015; decision to be announced at the end of June:

Technologies / Techniques: We continue to explore the use of automotive-grade LiDAR for the detection of road boundaries. This technique can provide lane centering information in the presence of certain boundary types (guardrail, Jersey barrier, tunnel) and could be combined with other sensory input for road boundary detection under more difficult conditions.

We are also exploring the use of low-cost GPS, odometry, and vision-based lane marking detection to achieve lane-level localization for autonomous driving.

Other Products associated: Software / Netware, We have ported our earlier Matlab implementation of LiDAR-based road boundary detection to C++ and are about to test it in our autonomous Cadillac SRX vehicle. The described techniques for low-cost localization have been coded in C++ and tested in both closed-course and real-world scenarios in McKeesport, PA near Pittsburgh and the Oakland university neighborhood of Pittsburgh, which is a fairly dense urban environment.

Impact: The developed techniques make it more cost-effective to provide sensing for autonomous and semi-autonomous vehicles for road boundary detection and localization.

Task List:
* Road boundary detection using LiDAR
* Multimodal (radar-LiDAR) context-specific sensing
* Low-cost localization
* Moving obstacle tracking

DETECTING DRIVER DISTRACTION, MAXINE ESKENAZI, CMU

http://utd.ices.cmu.edu/utd/projectitem.asp?ID=167

Participant Organizations: Yahoo!

Other Dissemination Activities: We have created a video about distraction detection that shows a demo of the detector.

Technologies / Techniques: Last year we collected a database of 50 subjects using a driving simulator while being distracted by email being read to them by their smartphones. That data was used to create models of distracted and non-distracted speech. A lot of work here concerned how to determine the ground truth of when a subject was distracted - by using steering wheel turning ratio, by using distance (or degree of change of distance) from the center line, etc.

From these two models we created the first speech-based distraction detector. The work on ground truth has lead us to rethink the way we use other indicators of distraction. We are now focusing on adding braking and gas pedal action as well as acceleration and deceleration to the speech information to make the detector more robust.

Other Products associated: Audio / Video; Databases. We have a video of a subject driving in the simulator using the distraction detector. We also can make the 50-subject database available to anyone who would like it - it includes audio, video and a rich system log.

The video can be found at:
https://drive.google.com/file/d/0B5uE144NzXLCZExqOXlTk5WV1E/view?usp=sharing

Task List: We have a working algorithm. And we finally have a solid definition of distraction ground truth. What we need to do next:
\- add brake pedal action to detector
\- add gas pedal action to detector
- add acceleration and deceleration to detector
- assess accuracy of the detector with each element separately and with all elements combined

PROGRAMMABLE AUTOMOTIVE HEADLIGHTS, SRINIVAS NARISIMHAN, CMU
http://www.cs.cmu.edu/smartheadlight/

Participant Organizations:
Ford Motor Company; Dearborn, Michigan; Financial Support
Intel Corporation; Santa Clara, California; Financial Support
Office of Naval Research; Arlington, Virginia; Financial Support
National Science Foundation Grant; Arlington, Virginia; Financial Support

Other Collaborators:
Anthony Rowe, Assistant Research Professor, Electrical and Computer Engineering and CyLab, Carnegie Mellon University

Other publications, conference papers and presentations:


Other Dissemination Activities: Demonstration for Anthony Foxx (U.S. Secretary of Transportation)
Demonstration for Chinese media delegation as part of a Pittsburgh visit by Madam Liu, the Vice Premier of China
Demonstration for members of the PA House of Representatives House Transportation Committee
Demonstration for Vinn White, Senior Policy Advisor, Office of the Secretary of Transportation
Demonstration for Intel delegation as part of the US-China Young Maker Competition
Demonstration at ITSA in Pittsburgh
Engaged with participants at the 2015 UTC Summit for Safety
Demonstration for those accepted to the CMU RI PhD program
Demonstration for students at the CMU Graphics Open House
Demonstration for various speakers for the RI VASC Seminar Series
Demonstration for U.S. and Japanese visitors from Toyota
Demonstration for Koito manufacturing
Demonstration for Scientific American Magazine
Demonstration at the IEEE International Conference for Computational Photography
Demonstration for Mahindra automotive

Technologies / Techniques:
We have developed a hardware interface that enables high-bandwidth, low-latency transfer of data from a computer to the headlight. With this hardware, the headlight can react to the environment within 1.5 ms, which is 1 ms faster than before. With the new design, latency is deterministic and does not vary with the light pattern.

Other Products associated: Data & Research Material; Software / Netware

Impact: We have engaged in many discussions with automotive companies and headlight manufacturers to bring this one-of-a-kind headlight to market. Through demonstrations and participation in meetings/conferences, we have engaged in regulatory discussions regarding U.S. adaptation of dynamic headlights.

Impact in other disciplines: The underlying technology that we have developed can be utilized in other disciplines that make use of imaging and illumination. For example, the system can be used in computational photography to intelligently illuminate high-speed events.

Task List: System code has been optimized for speed. A circuit board was developed to increase data throughput from the computer to the headlight. The footprint of the headlight has been significantly decreased in size. The headlight, with these new changes, has been tested on the road. We are currently developing new algorithms for use with various headlight applications.
Mobility and Data Analytics

**AUTOMATIC COUNTING OF PEDESTRIANS AND CYCLISTS, BERNARDO PIRES, CMU**

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

**Participant Organizations:**
City of Pittsburgh, Department of City Planning (Kristin Saunders, Bicycle/Pedestrian Coordinator) Objective of project is for Collaborative Research in which the City selects relevant data collection areas and times.

**Other Dissemination Activities:** Participation and Device Demonstration at the ITS America Annual Meeting, May 31st - June 3rd, 2015.


**Other Products associated:** Data & Research Material; Instruments or equipment; Software / Netware; This project entails the creation of a data collection device (already completed), the collection of public video data (approximately 20 hours have already been collected), and the creation of data labeling software as well as automatic counting software (under development).

**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.

**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.

**Task List:**
- Review of methods in the literature
- Implementation of state of the art detector
- Selection and purchase of equipment
- Assembly of data collection device
- Development of data labeling tool (shared with cell-phone detection project)
- Collection of training dataset
- Labeling and preparation of dataset
- Training and testing of bike/pedestrian classifier
- Integration with Mechanical Turk assisted counting

**MOBILITY DATA ANALYTICS CENTER, SEAN QIAN, CMU**

**Journal publications:** Yiming Gu, Sean Qian, Xiao-Feng Xie and Stephen Smith, An unsupervised learning approach for analyzing traffic impacts under arterial road closures: case study of East Liberty in Pittsburgh, submitted to Journal of Transportation Engineering ASCE.

**Books or other non-periodical, one-time publications:** Jackson Whitmore, Xidong Pi and Sean Qian, Performance Metrics for public transportation systems: the case study of Port Authority, technical report

**Other publications, conference papers and presentations:** Present the work to the City of Pittsburgh, and TRB community

**Other Products associated:** Software / Netware. The team is building a data engine and web application to archive, process and visualize traffic related data.

**Impact:** Mobility Data Analytics Center aims at building a centralized data engine to efficiently manipulate large-scale data for smart decision making. Integrating and learning the massive data are the key to the data engine. The data engine will first integrate disparate data sets from various sensing systems deployed or used by various agencies, private firms and individual travelers. Integrated data convey the information regarding traveler’s behavior and system performance, which can be learned and analyzed in the data engine. The ultimate goal of understanding massive data is to accurately estimate the historical usage of the transportation infrastructure and to forecast its future performance. To efficiently balance the infrastructure supply and demand, optimal decisions on management strategies, policies and adoption of technologies can be made.
Impact in other disciplines: The data are potentially useful for research in public policy, economics, social science, etc.

Task List: We are halfway done for each of the three tasks: 1) Data integration and system enhancement; 2) data analytics for public transit and arterial traffic data; 3) establish a network model to describe users' behavior.

NETWORK TRAFFIC MODELING AND SIMULATION FOR AUTONOMOUS VEHICLES, SEAN QIAN, CMU

Journal Publications: Zhen (Sean) Qian, Jia Li, Michael Zhang, Haizhong Wang, Modeling Heterogeneous Traffic Flow: A Pragmatic Approach, submitted to Transportation Research Part B.

Other publications, conference papers and presentations: Present the conceptual work in TRB 2015

Impact: Modeling dynamics of heterogeneous traffic flow is central to the control and operations of today’s increasingly complex transportation systems. We develop a macroscopic heterogeneous traffic flow model. This model considers interplay of multiple vehicle classes (such as regular vehicles and autonomous vehicles), each of which is assumed to possess homogeneous car-following behavior and vehicle size.

Task List: We have completed task 1 "review of AV control specifications" and Task 2 "two-class traffic flow model".

MODELING TRANSIT PATTERNS VIA MOBILE APP LOGS, ANTHONY TOMASICO, CMU

Technologies / Techniques: Machine learning models to analyze and map tracing information to transit density.

Task List:
- Preliminary analysis of logs (done)
- Machine learning models to recognize a valid "trip" from the logs (done)
- Visualization of generated trips (done)
- Preliminary machine learning models to recognize user state (to do)
- Integration of models into Tiramisu (to do)
- Extraction of model results from Tiramisu to visualization tool (to do)

Policy

SAFETY ASSESSMENT OF CONNECTED VEHICLES, CHRIS HENDRICKSON, CMU

Journal publications:


Under Review, Accident Analysis & Prevention.

Other publications, conference papers and presentations:

Impact: We bounded the increase in vehicle miles traveled was done in order to begin to consider the effects that a fully automated vehicle environment could have to the current transportation system if people who usually do not drive often due to bad health, age, etc. began to drive as much as those who do drive. The primary source of data for this project is the 2009 National Household Transportation Survey (NHTS), which provides information on current travel characteristics of the U.S. population. The changes to the total VMT are estimated by examining three possible demand wedges. In demand wedge one, the assumption made is that non-drivers would travel as 10 much as the drivers within each age group and gender. Demand wedge two assumes that the driving elderly without medical conditions will travel as much as young adults (ages 19-64) within each gender. Demand wedge
three makes the assumption that drivers with medical conditions will travel as much as the drivers without medical conditions within each age group and gender in a fully autonomous and connected vehicle environment. The combination of the results from all three demand wedges represents an upper bound of 297 billion miles or a 12% increase in overall VMT. Since traveling has other costs than driving effort, this estimate serves to bound the potential increase from these populations to inform the scope of the challenges, rather than forecast specific VMT scenarios. The results from this paper could be used to bound environmental and roadway management impacts, etc. from an increase in VMT from under-served populations.

- The cost analysis project evaluates the economic feasibility of large-scale deployment of current BSM, LDW, and FCW crash avoidance systems within the light-duty vehicle fleet by conducting a net-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. 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 future travel patterns of the disabled and elderly populations due to 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. Bounding the increase in vehicle miles traveled in an automated vehicle environment should provide a basis for both transportation professionals and policy makers to begin to consider the effects that a fully automated vehicle environment could have to the current transportation system if people who usually do not drive often due to bad health, age, etc. began to drive as much as those who do drive.

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.

**Task List**

Task 1: Assessment of direct savings from crash avoidance, including vehicle damage and injury.

Task 2: Assessment of potential indirect savings from crash avoidance due to reduced congestion from crash incidents, reduced emergency response, and changes to design criteria and investment decisions including but not limited to capacity of lanes, traffic signal designs, in-road communication devices, clear zone investments and dynamic message signs will be evaluated.

Task 3: Assessment of equilibrium changes in roadway travel, including rebound effects of more driving due to autonomous vehicles and alternative fuels (since battery vehicles will have lower per kilometer costs).
Task 4. Connected vehicles' impact on transit and other vehicles and how route decisions will change based on real-time passenger information will be examined and evaluated using data from the Pittsburgh test-bed and elsewhere.

**ASSESSMENT OF COST-EFFECTIVENESS OF PENNSYLVANIA’S SAFETY INSPECTION PROGRAM, H. SCOTT MATTHEWS, CMU**

**Participant Organizations:** Compuspections, LLC; Pennsylvania Department of Transportation

**Journal Publications:**

**Other Products associated:** Databases. We acquired data from Compuspections (our industry partner) as well as Pennsylvania Department of Transportation and have created one large database with all detail about PA vehicles as well as their inspection results.

**Impact:** Our research impacts drivers of personal vehicles by evaluating whether the vehicle safety inspection program is beneficial. To date, we have found that in PA specifically, there seems to be a positive benefit from the program, especially in older vehicles. Currently, we are evaluating whether there is a reduction in fatal crashes due to the implementation/requirement of the program as compared to other states without this program.

**Task List:** Cost Benefit Analysis of vehicle safety inspections in states with versus without the inspection program is still in progress

**EVALUATING THE OPPORTUNITIES FOR COST SAVINGS AND ENVIRONMENTAL BENEFITS OF COUPLING SOLAR ENERGY AND ELECTRIC VEHICLES IN CITY OF PITTSBURGH MUNICIPAL OPERATIONS, CONSTANTINE SAMARAS, CMU**

**Participant Organizations:** City of Pittsburgh, Pittsburgh Parking Authority

**Other Collaborators:** Jeremy Michalek, CMU; Avi Mersky, CMU

**Other Dissemination Activities:** 10 March 2015 – PI presented project scope and ideas to Deborah Lam (Chief Innovation Officer of the City of Pittsburgh) and Grant Erwin (Sustainability Manager for the City of Pittsburgh) as part of set of presentations organized by Rick Stafford, and received helpful feedback from stakeholders.

**Task List:**
Task 1. Collect and assemble data set of City of Pittsburgh light duty vehicles in the municipal fleet. Collect, assemble and map data on existing available land area in municipal fleet garages and parking lots. Collect and assemble ensemble of PEV and solar technology options for municipal implementation, including capital cost, operating cost, energy consumption, energy generation, and life cycle environmental air pollutant and greenhouse gas emissions. (Project months 1-3)
Task 2. Model the changes in life cycle local and regional air pollutant and greenhouse gas emissions of multiple PEV and solar PV technology options for the City of Pittsburgh. The model will also include financial outcomes relevant to City decision makers, including expected capital outlays, and changes in operations and maintenance expenses. (Project months 3-6)
Task 3. Generate final report for the City of Pittsburgh and discuss results with stakeholders. (Project month 6)

**Other**

**EFFICIENT 3D ACCIDENT SCENE RECONSTRUCTION, LUIS E. NAVARRO-SERMENT,**

**Other collaborators:** Allegheny County Emergency Services, Pennsylvania Turnpike Commission

**Technologies / Techniques:** As part of two other projects, we developed a methodology to take pictures of an accident scene and construct a 3D model; this is based on open-source structure-from-motion software and our own scripts and procedures. At the core of this methodology is an Android App, which we developed to assist users with the task of collecting the photographic evidence that is used to reconstruct the scene. In this project we
have made considerable improvements to our assistive image capture application, making it more flexible and easier to use through the introduction of additional visual markers and spoken instructions.

Additionally, we have built a low-cost 3D scanner, using a Hokuyo line scanner that was purchased for a past project. This is a servo-controlled platform that sweeps the line scanner, and integrates a series of measurements into a 3D point cloud. The point cloud will be used as ground truth for reconstruction evaluation purposes. We plan to focus our evaluation on two properties: geometric accuracy and completeness. Geometric accuracy measures how close the reconstructed model \( R \) is to the ground truth model \( G \) (meters). Similarly, completeness measures how much of \( G \) is modeled by \( R \) (percentage).

**Impact:** We anticipate that our tool will have a significant impact in reducing the time and complexity involved in documenting road accidents. More importantly, because emergency personnel are vulnerable while working close to traffic, any improvement in response and remediation times reduces their exposure to danger, effectively reducing risk for responders. Additionally, shorter remediation times reduce traffic delays, congestion and secondary accidents. It has been estimated that one minute of full highway closure can cause up to one mile of congestion. Improving the quality of accident investigations will give better insight into the causes of accidents and thereby inform strategies to improve safety.

**Impact in other disciplines:** By making 3D reconstruction more affordable, we expect to see users from other areas adopting this technology, e.g. insurance companies, architects, contractors.

**Task List:**
- Study work practices
- Develop user assist app
- Package code for practical use
- Evaluate system
- Develop deployment plan

**ENHANCING THE SAFETY OF VISUALLY IMPAIRED TRAVELERS IN AND AROUND TRANSIT STATIONS, M. BERNADINE DIAS, CMU**

http://www.es.cmu.edu/~navpal;

**Participant Organizations:** Western Pennsylvania School for Blind Children (WPSBC), Blind and Vision Rehabilitation Services of Pittsburgh (BVRS)

**Other Collaborators:** Dr. Aaron Steinfeld, Postdoctoral Fellow Byung-Cheol Min and undergraduate student Eric Hochendoner, CMU. Dr. George Zimmerman from the School of Education Vision Studies Program Dr. Hassan Karimi from the School of Information Sciences Geoinformatics Laboratory and Dr. Jonathan Pearlman from Human Engineering Research Labs, University of Pittsburgh.

**Other publications, conference papers and presentations:** On January 12, Byung-Cheol Min gave a talk entitled “Enhancing Urban Navigation for Blind Travelers with a Smart Phone Aid that Benefits from a Network of Trusted Sources” at the Transportation Research Board 94th Annual Meeting in Washington D.C. His talk highlighted T-SET UTC funded work.

On May 15, Bernardine and Pitt collaborators attended the Accessible Transit Wayfinding Workshop hosted by the Port Authority of Allegheny County. The workshop included several presentations by Port Authority representatives and faculty from Pitt and CMU, with Q&A and discussion throughout. Bernardine presented our T-SET UTC funded work.


**Other Dissemination Activities:**

On May 26, 2015, Bernardine gave a talk at the Robotics & Automation Technologies for Humanitarian Applications: Where we are & Where we can be (RATHA) workshop, part of ICRA 2015. The goal of the RATHA workshop was to “understand the current and future role robotics and automation technologies play in alleviating suffering of humanity in times of need.” In her talk entitled “Bridging the Gap Between Academic
Work and Field Deployments: A Decade of Lessons Learned” Bernardine mentioned our NavPal project and acknowledged T-SET UTC funding.

Technologies / Techniques: Given the nature of transit stations, we have begun to explore how our work can straddle both indoor and outdoor scenarios, as well as transitions between indoor and outdoor areas. We are exploring WiFi-based indoor localization, as well as a framework for categorizing and utilizing accessible landmarks to enhance navigation and localization. These landmarks can also be inserted and updated using our trusted sources framework. Our current work is combining the indoor and outdoor navigation strategies and techniques, and enhancing them with access to the trusted sources framework.

Impact: Findings from this work are impacting several fields in useful ways. The trusted sources framework has already garnered interest from several groups spanning non-profits and industry, and will inform future technology development in the field of assistive technology (a subfield of robotics). Furthermore, our prototype solution contributes to the state of the art in assistive technology research.

Impact in other disciplines: While our focus is in the discipline of robotics, and more specifically in assistive technology, the outcomes of this work will also have impact in the fields of orientation and mobility (the specialists who train blind and visually impaired people to navigate), accessible transportation, and human-computer interaction. Orientation and mobility experts have shown interest in how our work can assist them to further enhance the independence and safety of blind and visually impaired people. Transportation groups such as Port Authority in Pittsburgh are interested in how this work can be used to improve the services they offer to riders with disabilities. Human-computer interaction researchers who focus on interface design are interested in what we learn about accessible interfaces to technology tools.

Task List: Our task list was to focus on technology development in the spring, user testing and iterative technology enhancement in the summer, and a small-scale technology deployment in the fall. Thus far we have been focusing on technology development, dissemination, and planning of user tests."