Project Title: Radar-Camera Infrastructure for Automotive Safety

Recipient/Grant (Contract) Number: Carnegie Mellon University, Grant #: 69A3552344811

Center Name: Safety21 National University Transportation Center for Promoting Safety

Research Priority: Promoting Safety

Principal Investigator(s): Swarun Kumar Carnegie Mellon University

PI Contact: swarun@cmu.edu

Project Partners:

- Pittsburgh Parks Conservancy
- City of Pittsburgh Department of Mobility and Infrastructure

Research Project Funding: $200,000.00

Project Start and End Date: 07-01-2023 to 06-30-2024

Project Description:

Safety is a critical strategic goal of the U.S. DoT according to its RD&T plan with zero fatalities being a grand challenge. This proposal directly addresses pedestrian safety - critical to automotive safety. We target the design of roadside infrastructure at critical points along roadways where pedestrian accidents are likely, such as intersections, sharp curves or hidden driveways. Many such locations involve blindspots, where the vehicle or any single roadside sensor only has a partial view of its environment owing to occlusions. There is rich prior art on sensing systems for blindspot monitoring ranging from the cameras, LiDAR or custom (usually visual) sensors, many of which rely on multiple sensors placed at different vantage points adding to cost and installation burden. What is lacking is a sensing platform that can be placed at a single vantage point, and yet offers a seamless "through-occlusion" imaging, while operating over long-range (hundreds of meters) and offering high-resolution (sub-centimeter). In this proposal, we design a high-resolution imaging system despite obstructions using two complementary platforms - a mmWave radar and camera. We specifically focus on single-chip automotive mmWave radars that are widely deployed in cars as collision sensors, yet are extremely compact - merely centimeters across. Our key technical insight is that both the mmWave radar and camera have complementary strengths. While the mmWave radar offers extremely high depth-resolution (centimeter-scale at even hundreds of meters) and through-occlusion imaging, its spatial resolution is extremely poor (several degrees). In contrast, cameras offer poor depth resolution (several meters, especially at long range), but high spatial resolution. Our work explores mechanisms to achieve the best of both these systems on a single combined platform. Unfortunately, a classical data-driven sensor fusion does not directly apply in our case mainly due to the unique attributes of mmWave radar images. Specifically, mmWave radar outputs experience clutter artifacts that must be carefully eliminated to prevent spurious detected objects. Our preliminary work on mmWave-and-camera based depth sensing at IROS'22 explicitly models and corrects for this effect prior to fusing sensed data. Through the proposed work, we seek to generalize this to generate high-resolution 3D point clouds, including through-occlusions. Beyond technical research contributions, our objective is to demonstrate end-to-end benefits of our system for existing stakeholders. To this end, we will further fully implement and evaluate the system on commodity mmWave platforms and camera systems with the support of Bosch, who has generously offered in-kind support (lab spaces, equipment, personnel time). Our designs will be deployed at pedestrian intersections, with our first deployment enabled through active collaboration from the City of Pittsburgh Department of Mobility and Infrastructure, who we are in conversations with as a deployment partner. We are acutely aware that pedestrian safety incidents impact under-served, low-income and the housing displaced at a rate much higher than the general population. To this end, we have engaged with the Pittsburgh Parks Conservancy as an equity partner to identify the needs of the community in/around Mellon Square Park in shaping our first deployment.

Outputs:

The proposed work's key anticipated outputs include:

- Research Impact: The proposed work will develop a fundamentally new approach to fuse radar and camera data to sense objects of interest occluded from the view of a single vantage point. This has important implications for transportation safety and pedestrian safety systems in particular. Publications: Research developed through the proposed work will be disseminated through publications at major international venues including wireless, sensing systems, robotics and cyber-physical systems venues.

- Data: There is a significant lack of public open-source datasets that combine mmWave radar output alongside camera visual data. Research data developed through the project will be released through open-source permissive licenses to address this gap.

- Software: Source code and associated software systems will be developed to fuse and combine mmWave and camera data.

- Patent Filings: The proposed work will lead to patent filings to protect the intellectual property on the radar-camera sensing system.

- Student Training: One Ph.D. student will be trained during the course of the research. The student will actively collaborate with Bosch and the City of Pittsburgh.

- Pilots: The proposed work will lead to pilot deployments in a City of Pittsburgh location to demonstrate a proof-of-concept through-obstruction pedestrian sensing system.

Outcomes/Impacts:

The proposal directly addresses the safety of automotive systems, specifically pedestrian safety. The proposed work aims to develop fixed infrastructure for pedestrian accident-prone regions to sense the environment and report hazardous situations even if hidden from direct view. The proposed work will create a new model for developing low-cost, easy-to-deploy infrastructure for pedestrian safety. The proposed work has the potential to develop new research products and intellectual property on through-obstruction sensing systems from a single vantage point. Anticipated outcomes will include the development of research publications, technical reports and patents based on the proposed work. We believe that the proposed work also has the potential to shape regulatory requirements for advanced pedestrian safety systems in accident-prone regions. The proposed work will be implemented and piloted in Pittsburgh through partnerships with the City and Bosch, who has also offered in-kind support in terms of equipment costs, access to lab infrastructure and personnel time. Pedestrian safety incidents disproportionately impact low-income communities and the homeless in particular. The proposed work has a specific mandate to address pedestrian safety in these contexts. In collaboration with our equity partners, we will identify and pilot the first pilot deployment of our platform to address this goal.