Project Title: Computational Imaging for Improving Vehicle Safety

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Center Name: Safety21 National University Transportation Center for Promoting Safety

Research Priority: Promoting Safety

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Project Partners:

- Ubicept Inc.
- City of Pittsburgh, Department of Mobility & Infrastructure

Research Project Funding: $255,951.00

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

Project Description:

This project investigates the design and deployment of sensors and associated algorithms for handling harsh imaging conditions. We are particularly interested in depth perception in rain, snow and fog. By expanding the depth range at which objects can be reliably detected, especially in dense fog, the project will facilitate a higher level of safety for vulnerable road users. The project aims to improve perception in both autonomous as well as assisted settings; in the latter, we will augment perception of human drivers to better identify vulnerable road users in dense fog/rain. Rain, snow and fog present challenging operating scenarios for camera and LIDAR-based depth perception. For passive cameras, imagery in such weather results in a loss of contrast. In turn, this makes it harder to match features across views, which reduces the effectiveness of stereo-based depth estimation. LIDAR, on the other hand, works on the principle of time of flight, measured by pulsing a laser and using a single-photon avalanche diode (SPAD) to measure the arrival time of the first returning photon. Here, fog and rain generate spurious photon arrivals that severely compromise the quality of depth measurements. We approach this problem as one of joint design of sensors and algorithms to overcome the challenges imposed by the physics of image formation. Our main insight is that improved depth perception can be improved via careful imaging and algorithmic design that allows blocking of photons from the medium while preserving those from the scene of interest. This approach is central to very successful microscopy techniques such as confocal imaging, and diffuse optical tomography, for imaging in highly scattering media like biological tissue. We will leverage this core intuition but expand it to macroscopic imaging in the real world. Improving perception in dense scattering media by blocking undesired photons requires imaging systems that can selectively choose between favorable light paths in the scene against unfavorable ones. Our proposition is to build a structured light system with a high-speed projector and a ultra-high speed SPAD array. With this setup, we will design patterns that will avoid single-bounce light paths off the medium. An example of this can be seen in prior work by the PI where a laser line is used to illuminate a scene while sensing it with a line. This imaging configuration ensures light at the intersection of laser and the sensor planes (which is a line in the world) is preferred over other light paths induced by scattering. We will leverage work by the PI in high-speed depth imaging using SPAD devices; we will expand upon such a concept for the case of scattering media. This project will enhance the range of scenarios where a vehicle can safely operate in. Specifically, it will lead to increased range in depth perception in fog and rain, improving safety of vulnerable road users. In subsequent years, we will look at imaging around visual occlusions (like cars) using non-light-of-sight techniques. This will lead to broader adoption of computational imaging with the eventual goal of increasing safety in transportation systems.

Outputs:

The primary output of this project will be in the form of novel depth imaging devices and associated algorithms that can image farther in bad weather. So, we expect the following tangible outputs:

- Imaging hardware, schematics and prototypes

- Software for processing data released publicly under open-source licenses
- Papers, invention disclosures, and (likely) patents
- Dataset of measurements made in bad weather
- Presentations

Outcomes/Impacts:

Thie project aims to improve perception on vehicles operating in adverse weather conditions with the goal of improving safety of vulnerable road users. Since perception is a primary tool by which we sense the world, improving perception helps both autonomous vehicles and assisted vehicular technologies. For autonomous vehicles, improving range of perception in bad weather improves safe operation. The technology developed in this project will help assist human drivers to drive safer in bad weather by augmenting their visual perception using measurements made by our system.