Capstone Project: Distributed Millimeter-wave Radar for Future Autonomous Vehicles and Safety

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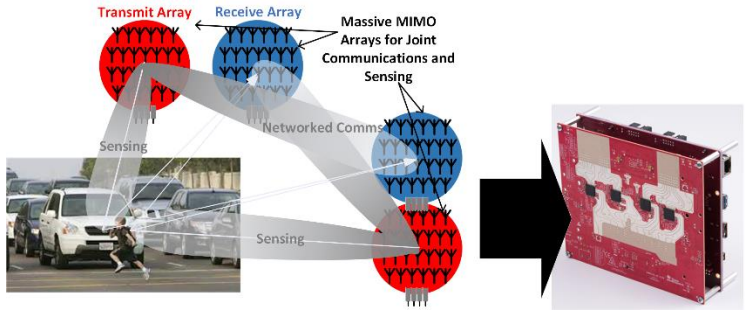
The goal is to demonstrate a network of radar nodes that could be integrated into future autonomous systems and instantaneously generate a comprehensive RF map of objects and activities in indoor or outdoor environments. This project will require a cohesive team of students with interests in radio, signal processing, and computer engineering.



Background: Rapid advances in millimeter-wave electronics have made commercially available radar systems that operate at 77 GHz available at low cost. These radars offer resolution at centimeter scales have applications ranging from perception for vehicular autonomy to privacy-preserving sensing for eldercare. An example of a commercially available multi-antenna millimeter-wave radar is the TI TIDEP-01012 shown in the adjacent figure. These components offer RF interfaces as well as powerful on-chip signal processing capability.

Problem: Millimeter-wave radar offers excellent range resolution and coupled with multi-input/multi-output (MIMO) signal processing techniques can improve the resolution and flexibility to produce an instantaneous map of an indoor or outdoor environment. However, millimeter-wave radar systems do not see around corners or function well in non-line-of-sight conditions which limits the safety and robustness of relying on such as radar system.

Proposed Solution: By employing a distributed network of radar transmitters and receivers, the project will improve the resolution and reliability of RF imaging and inference. This project will aim for a demonstration of a 2 x 2 MIMO radar system, as shown in the figure above, as the first step in validating the concept of a network of cooperating radar units. The 2 x 2 demonstration system requires solving core problems of coordination between hardware, signal processing, and image processing, setting the stage for scaling to larger distributed radar systems in the future.

Suggested Tasks: The sequence of tasks in this project is designed so to successively build the team's experience and the complexity and capabilities of the system being realized.

1) Imaging with a single MIMO radar board: With the TI radar evaluation hardware at 77 GHz, develop algorithms to imaging stationary scenes and moving objects using the tools provided by TI. This requires understanding the fundamentals of MIMO radar, getting familiar with hardware programming tools and signal processing tools provided by TI, applying them to extract radar point clouds, and applying a second layer of signal processing algorithms to draw inferences about the scene. Depending on their interests, the team may decide to improve upon the baseline signal processing algorithms provided by TI, but this is not required for the goal of demonstrating distributed radar.

2) Synchronizing and calibrating two MIMO radar boards: As a fundamental building block of distributed radar, the team will demonstrate that radar waveforms transmitted by one TI board and received by another board can be used to draw useful inferences. In order to do this, the two boards must be synchronized in frequency and timing, and a number of different combinations of hardware and software techniques will be explored to achieve this.
3) Imaging with two synchronized MIMO boards: Once two boards have been synchronized, the team will devise experiments to evaluate a couple of canonical advantages of distributed radar: increased spatial resolution due to larger effective aperture, and diverse looks at the scene (particularly useful for objects with highly reflective surfaces).
4) Wireless synchronization and communication: While the lowest risk approach to synchronization, calibration and data sharing between multiple radar sensors is to connect them by wires, this limits the distances between sensor nodes. Depending on time and interest, the team would explore design of wireless synchronization techniques (e.g., via a distributed pilot tone) and high-capacity wireless data links.