[1-minute talk]

Hello,

My name is Josiah Smith. I am a PhD student at The University of Texas at Dallas pushing the limits of high-resolution radar imaging and deep learning.

In this work, we develop a fully integrated efficient millimeter-wave imaging system capable of reconstructing 3-D holographic images of hidden and concealed items. We present a novel efficient MIMO-ISAR image reconstruction algorithm and construct a mechanical scanner for synthesizing cylindrical and rectangular apertures. This project demonstrates advantages over previous work by increasing spatial resolution and providing rotational invariance, while decreasing system cost, scanning time, and computational expense.

To get an inside look at the progress and novelty of this research, please attend my five-minute video on “3-D Holographic Near-Field MIMO-ISAR Millimeter-Wave Imaging.” Thank you

[5-minute talk]

Hello,

My name is Josiah Smith. I am a PhD student at The University of Texas at Dallas pushing the limits of high-resolution radar imaging and deep learning.

Today, I’m going to show you the strides we have been making in near-field MIMO-ISAR millimeter-wave imaging.

In this presentation, I’m going to guide you through the innerworkings of our fully integrated rotational inverse synthetic aperture radar system capable of reconstructing high-fidelity 3-D holographic images.

Millimeter-wave sensors have recently emerged as a promising solution to a variety of sensing problems in the arenas of security sensing, automotive radar, high-resolution imaging, and many more. Additionally, millimeter-wave radar devices are becoming increasingly affordable due to advancements in system-on-chip RF integrated circuit technology.

The goal of this work is to construct a high resolution mmWave imaging system for near-field holographic 3-D image reconstruction using novel ISAR techniques and commercially available mmWave radar sensors.

To accomplish this goal, we develop an efficient Fourier-based algorithm for MIMO-ISAR image reconstruction and build a three-dimensional mechanical scanner to synthesize both rectangular and cylindrical apertures.

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First, we present a novel image reconstruction algorithm for cylindrical MIMO-ISAR by pairing a multistatic-to-monostatic approximation with an efficient Fourier-based SISO image reconstruction algorithm. The pairing of multistatic-to-monostatic conversion with rotational ISAR allows us to drastically increase scanning efficiency by using a MIMO array without requiring more computationally taxing MIMO image reconstruction algorithms.

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Next, we assemble a fully integrated system with vertical, horizontal, and rotation scanning capabilities allowing for comparison between rectangular SAR and rotational ISAR. The entire scanner is controlled through a custom-built MATLAB graphical user interface that sets up the radar device and controls the scan.

We will proceed to reconstruct high resolution holographic images of the knife shown to the right. Note the notch and serrated edge of the blade, which will be visible in the subsequent images.

[Next slide]

We first compare images from a SISO array of 512 monostatic vertical elements spaced by a quarter wavelength. To scan at each of the 512 vertical locations, the entire scan took 137 minutes to complete. In contrast, the scan using a MIMO array of the same size took 17 minutes in total. Both the images show a high-quality reconstruction of the knife blade with the notch and serrated edge clearly visible.

[Next slide]

Next, we use the 2-D horizontal and vertical scanning axes to produce 3-D holographic images from a rectangular SAR aperture. We consider multiple cases, 1) the knife blade is parallel with the x-y aperture plane, and 2) the knife blade is perpendicular to the x-y plane. The orientation of the knife with respect to the scanner has substantial implications on the image quality.

The images on the right compare the reconstructed images of the knife blade when the knife is parallel and perpendicular to the scanning plane.

This demonstrates the high dependence of the image quality on the knife orientation in the rectangular MIMO-SAR regime. While rectangular SAR can reconstruct high-resolution 3-D images of reflective targets, the rotation of the target drastically changes the quality of the resulting image.

By comparison, rotational MIMO-ISAR is rotational-invariant since the target is scanned across a full 360-degree aperture. Further, this results in improved spatial resolution over the rectangular SAR imaging regime.

In conclusion, we developed a high resolution 3-D near-field imaging system based on low-cost system-on-chip mmWave FMCW radars, a multistatic-to-monostatic conversion, and an efficient Fourier-based rotational ISAR imaging algorithm.

Our experimental results validate our novel MIMO-ISAR 3-D holographic image reconstruction algorithm, demonstrate improved scanning efficiency over SISO systems, while maintaining high-resolution image quality, and establish the rotational-invariance advantage of rotational ISAR over rectangular SAR.

Proved by simulation and empirical measurement, our fully integrated system allows for efficient near-field MIMO-ISAR mmWave imaging offering an elegant solution to many near-field imaging and sensing problems including security sensing, through-the-wall imaging, and concealed weapon detection.

My name is Josiah Smith and I want to thank you for attending this presentation.