Autonomous Navigation using mmWave Radar Sensors

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***Abstract*—This demo presents a real-time radar-only odometry and mapping system using four Texas Instruments IWR6843ISK mmWave radar demo boards. The system estimates the motion of a mobile robot using Doppler and angle information extracted from the radar point clouds, without relying on scan matching, cameras, or inertial sensors. Velocity is estimated directly from Doppler measurements and integrated over time to reconstruct the robot trajectory and map the surrounding environment. All processing is done on a central laptop running ROS2, with real-time visualization of both odometry and mapping in RViz. The radar setup is compact, self-contained, and designed for operation in GNSS-denied or visually degraded environments. This work highlights the unique potential of mmWave radar for ego-motion estimation and mapping, with robustness to clutter, lighting changes, and occlusions. The novelty lies in the use of Doppler-only odometry from multiple synchronized TI demo boards, without traditional scan matching or SLAM back-ends.**

***Index Terms*—mmWave radar, radar odometry, doppler-based localization, radar-only SLAM , GNSS-Denied navigation.**

I. Introduction

This demo presents a real-time radar-only odometry and mapping system using four synchronized TI IWR6843ISK mmWave radar boards. It estimates robot motion using Doppler and angle data without relying on cameras, inertial sensors, or scan matching, making it ideal for GNSS-denied or visually degraded environments.

A. Technical Details

The demo will showcase a **real-time Simultaneous Localization and Mapping (SLAM)** system using **mmWave radar sensors** (Texas Instruments' **IWR6843ISK** sensors). The primary goal of the demo is to demonstrate how **Doppler radar data** can be used to estimate the robot's **velocity** and provide **odometry** for localization and mapping purposes. The system is designed for autonomous navigation applications, such as those found in automotive or robotics fields. Below is a detailed breakdown of the hardware and software components involved in the demo setup

B. Units

- **Hardware:** 4 × Texas Instruments IWR6843ISK mmWave radar demo boards, and central processing laptop running Ubuntu 22.04 and ROS2 as depicted in Fig. 1.
- **Signal Processing:** Range-Doppler-angle cube computation for each sensor, Doppler-based velocity estimation, Odometry via extended Kalman Filter (EKF) from velocity estimates, Radar-based environmental mapping.
- **Doppler Velocity Estimation:** The radar sensors provide **Doppler information** that is used to estimate the robot's **velocity**. By analyzing the frequency shifts of the radar signals reflected by objects in the environment, the system can compute the **relative velocity** of the robot with respect to these objects. This velocity information is then used to update the **odometry** of the robot in real-time, allowing the SLAM algorithm to track its motion and accurately localize the robot in the environment. The platform's velocity is estimated by applying a **Least Squares** approach to the Doppler-shifted radar data and the corresponding **point cloud** measurements. The radar's Doppler shifts provide velocity estimates for each point in the environment, which are then aggregated to calculate the overall velocity of the platform. This method enables robust and accurate velocity estimation based on multiple radar measurements.
- **Extended Kalman Filter:** To estimate the robot's position over time, the system utilizes an EKF. The EKF is used to fuse the velocity data obtained from the Doppler measurements with the odometry calculations, resulting in an accurate position estimate. The EKF accounts for sensor noise and uncertainties by maintaining a probabilistic estimate of the platform's state, which includes both position and velocity. This allows the system to predict the future state of the robot, refine position estimates, and handle non-linearities in the motion model. The EKF processes the velocity and position information from the radar sensors to continuously update and refine the robot's trajectory in real-time.
- **3D Mapping using OctoMap:** The proposed system integrates **OctoMap**, a probabilistic 3D occupancy mapping framework, into the ROS2-based SLAM pipeline. OctoMap employs an efficient **octree data structure** to represent the environment in full 3D, capturing *occupied*, *free*, and *unknown* areas. This is essential for radar-only SLAM, where robust spatial reasoning must compensate for limited angular resolution.

The work is supported by the Luxembourg National Research Fund (FNR) through the CORE project R4DAR under grant `C23/IS/18049793/R4DAR`.

- **Software:** ROS2 for data handling and visualization
  Custom radar drivers and odometry estimation nodes
  Real-time visualization with RViz
- **No use of visual sensors**

C. Relevance to EUSIPCO

This demo aligns with the key topics of the EUSIPCO 2025 conference, particularly the *Automotive Radar Signal Processing* session. Our demonstration showcases how *mmWave radar sensors*, specifically the IWR6843ISK from Texas Instruments, can be leveraged for *real-time SLAM (Simultaneous Localization and Mapping)* in dynamic environments. By processing Doppler information from the radar, the system estimates the robot's velocity and performs odometry, enabling autonomous navigation—a crucial aspect of *automotive radar* technologies. This application contributes to advancements in radar signal processing for *autonomous vehicles* and can serve as a foundation for further research into radar-based localization and mapping techniques. This demo has not been presented earlier in any other conferences.

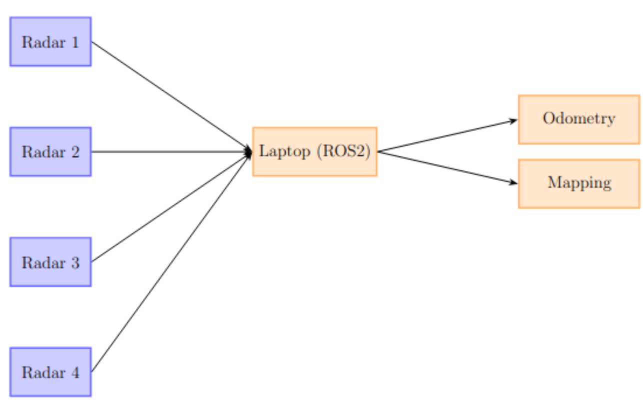

Fig. 1. System block diagram: Multi-radar Doppler processing for odometry and mapping.

D. Demo Logistics

- **Space Required:** Approximately 2m × 2m. A larger space or a corridor that the mobile stand can move for mapping would be preferable.
- **Power Requirements:** Standard AC outlet
- **Trolley or Mobile Stand:** A sturdy base with wheels for easy movement. Preferably with a locking mechanism to keep the trolley stable during demonstrations.
- **Internet:** Optional, for ROS logging/debugging
- **Provided Equipment:** Laptop, 4 × IWR6843ISK boards, mount or mobile base

Contact

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