3D Point Cloud Generation with Millimeter-Wave Radar

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Emerging autonomous driving systems require reliable perception of 3D surroundings. Unfortunately, current mainstream perception modalities, *i.e.*, camera and Lidar, are vulnerable under challenging lighting and weather conditions. On the other hand, despite their all-weather operations, today's vehicle Radars are limited to location and speed detection. In this paper, we introduce MilliPoint, a practical system that advances the Radar sensing capability to generate 3D point clouds. The key design principle of MilliPoint lies in enabling synthetic aperture radar (SAR) imaging on low-cost commodity vehicle Radars. To this end, MilliPoint models the relation between signal variations and Radar movement, and enables self-tracking of Radar at wavelength-scale precision, thus realize coherent spatial sampling. Furthermore, MilliPoint solves the unique problem of specular reflection, by properly focusing on the targets with post-imaging processing. It also exploits the Radar's built-in antenna array to estimate the height of reflecting points, and eventually generate 3D point clouds. We have implemented MilliPoint on a commodity vehicle Radar. Our evaluation results show that MilliPoint effectively combats motion errors and specular reflections, and can construct 3D point clouds with much higher density and resolution compared with the existing vehicle Radar solutions.

CCS Concepts: • **Human-centered computing → Ubiquitous and mobile computing**.

Additional Key Words and Phrases: FMCW Radar, SAR Imaging, Tracking, Radar Point Cloud

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1 INTRODUCTION

Recent years have witnessed a surging demand for autonomous driving, driven by which the automotive industry revenue will expand by 30% to about $1.5 trillion, and 15% of new cars sold are expected to be fully autonomous by 2030 [15]. However, such predictions are optimistically based on the resolution of major technical issues. Currently, even the most advanced self-driving systems are still conditional automation at the Level 3 [25, 57], *i.e.*, allowing driver "eyes-off" most of the time but with occasional intervention. One major challenge in the way is the accidental failure of system perception, which reduces safety factors and even causes fatalities [61, 62].

The perception function relies on sensors that robustly capture key information of surroundings, such as nearby vehicles, pedestrians, and lanes. A wide range of sensing modalities is already available on vehicles, such as Lidar and camera. However, these sensors are limited by their operating medium and may not function well under certain conditions. Specifically, Lidar relies on the projection of laser beams that cannot penetrate opaque obstacles and are vulnerable to failure in harsh weather conditions. Cameras passively capture light scattered by

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