

PROGRAM

**ADVANCED
INNOVATION
TECHNOLOGY
2026**

**January 12 (Mon) – 15 (Thu), 2026
Sala Danang Beach Hotel, Vietnam**

Organized by KIIS & KSPM

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YOLOv8-Based Estimation of Range and Velocity in OFDM Radar with Subcarrier Sparsity

Eun-A Ko¹, So-Yeon Jeon¹, Eui-Rim Jeong^{2*}

¹ Department of Artificial Intelligence, Hanbat National University, 125, Dongseo-daero, Yuseong-gu, Daejeon, Republic of Korea

^{2*} Department of Artificial Intelligence Software, Hanbat National University, 125, Dongseo-daero, Yuseong-gu, Daejeon, Republic of Korea

Corresponding author* : erjeong@hanbat.ac.kr

Abstract

This paper investigates the impact of subcarrier sparsity on multi-object range and velocity estimation performance in orthogonal frequency division multiplexing (OFDM) radar systems, a core technology for integrated sensing and communication (ISAC). A YOLOv8-based object detection model is employed to detect multiple targets using 2D range–Doppler maps generated from OFDM radar signals, enabling simultaneous estimation of range and velocity for each object. Simulation results demonstrate that velocity estimation performance is highly dependent on the number of OFDM symbols, with mean absolute error (MAE) decreasing significantly as the symbol count increases. In contrast, range estimation performance remains relatively stable without substantial degradation across varying levels of subcarrier sparsity. These findings suggest that the proposed approach exhibits robustness to subcarrier sparsity and can be effectively applied to various ISAC applications, including autonomous driving, intelligent transportation systems, unmanned surveillance, and next-generation communication–radar integrated systems.

Keywords: OFDM radar, YOLOv8, multi-object range and velocity estimation, subcarrier sparsity, integrated sensing and communication (ISAC)

1. Introduction

Recent advances in autonomous vehicles, intelligent transportation systems (ITS), unmanned surveillance, and smart cities have driven increasing interest in integrated sensing and communication (ISAC) technologies that enable simultaneous communication and sensing within a single system [1]. Among various ISAC approaches, OFDM radar systems have attracted significant attention due to their flexibility and compatibility with modern communication frameworks. This paper applies a YOLOv8-based object detection model to OFDM radar systems to analyze the impact of subcarrier sparsity on multi-object range and velocity estimation performance.

2. Literature review

Previous study has analyzed the impact of subcarrier sparsity on multi-object count estimation performance in OFDM radar systems [2]. However, these studies were limited to identifying the presence and number of objects without addressing the accuracy of estimating their physical parameters. To overcome this limitation, this paper extends prior work by conducting an in-depth analysis of how subcarrier sparsity affects the accuracy of multi-object range and velocity estimation.

3. Proposed Work

The received radar signals are processed to generate a 2D range–Doppler map, which serves as input to the YOLOv8 object detection model. The model detects multiple objects and simultaneously estimates their corresponding range and velocity. To prioritize radar performance, only a subset of subcarriers within the total bandwidth is selectively activated at uniform intervals. Subcarrier sparsity is defined as:

$$\text{Subcarrier Sparsity} = \frac{N_{\text{active}}}{N_{\text{total}}} \quad (1)$$

where N_{active} denotes the number of active subcarriers and N_{total} represents the total number of subcarriers. As subcarrier sparsity decreases, the spacing between adjacent active subcarriers increases, resulting in a reduction in the maximum unambiguous range.

Figure 1 presents the mean absolute error (MAE) of multi-object range and velocity estimation under different subcarrier sparsity levels and varying numbers of OFDM symbols. The simulation results reveal that velocity estimation MAE decreases significantly as the number of OFDM symbols increases. In contrast, while range estimation MAE exhibits gradual improvement with increasing signal-to-noise ratio (SNR), the degree of improvement is relatively modest compared to velocity estimation.

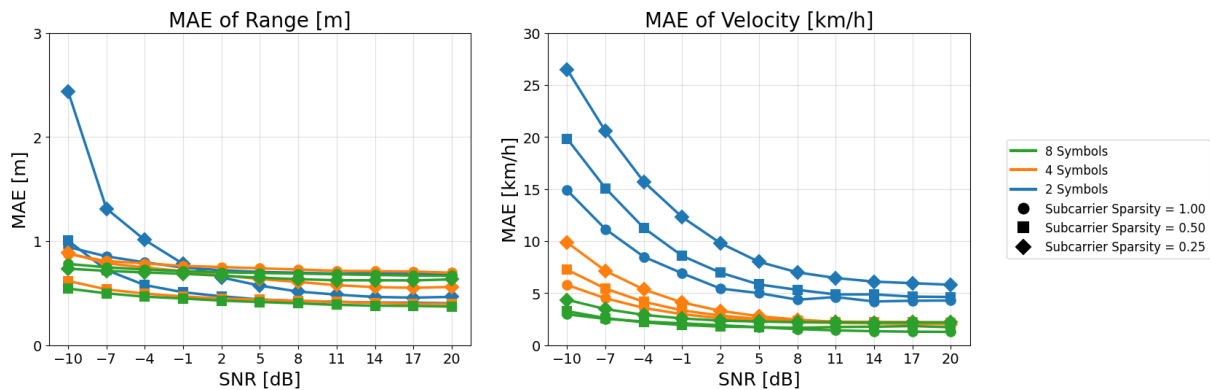


Fig. 1. Mean absolute error (MAE) of range and velocity estimation based on subcarrier sparsity and number of OFDM symbols

4. Conclusion

This paper investigated the impact of subcarrier sparsity on multi-object range and velocity estimation performance in OFDM radar systems using a YOLOv8-based object detection model. Simulation results demonstrate that velocity estimation performance is highly sensitive to the number of OFDM symbols, whereas range estimation performance remains stable without significant degradation even as subcarrier sparsity decreases. These findings indicate that the proposed approach exhibits robustness to subcarrier sparsity and can be effectively deployed across a wide spectrum of ISAC applications, including autonomous driving, intelligent transportation systems, unmanned surveillance, and next-generation communication–radar integrated systems.

5. References

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