World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:18, No:02, 2024

Integrating Radar Sensors with an Autonomous Vehicle Simulator for an Enhanced Smart Parking Management System

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Abstract : The burgeoning global ownership of personal vehicles has posed a significant strain on urban infrastructure, notably parking facilities, leading to traffic congestion and environmental concerns. Effective parking management systems (PMS) are indispensable for optimizing urban traffic flow and reducing emissions. The most commonly deployed systems nowadays rely on computer vision technology. This paper explores the integration of radar sensors and simulation in the context of smart parking management. We concentrate on radar sensors due to their versatility and utility in automotive applications, which extends to PMS. Additionally, radar sensors play a crucial role in driver assistance systems and autonomous vehicle development. However, the resource-intensive nature of radar data collection for algorithm development and testing necessitates innovative solutions. Simulation, particularly the monoDrive simulator, an internal development tool used by NI the Test and Measurement division of Emerson, offers a practical means to overcome this challenge. The primary objectives of this study encompass simulating radar sensors to generate a substantial dataset for algorithm development, testing, and, critically, assessing the transferability of models between simulated and real radar data. We focus on occupancy detection in parking as a practical use case, categorizing each parking space as vacant or occupied. The simulation approach using monoDrive enables algorithm validation and reliability assessment for virtual radar sensors. It meticulously designed various parking scenarios, involving manual measurements of parking spot coordinates, orientations, and the utilization of TI AWR1843 radar. To create a diverse dataset, we generated 4950 scenarios, comprising a total of 455,400 parking spots. This extensive dataset encompasses radar configuration details, ground truth occupancy information, radar detections, and associated object attributes such as range, azimuth, elevation, radar cross-section, and velocity data. The paper also addresses the intricacies and challenges of real-world radar data collection, highlighting the advantages of simulation in producing radar data for parking lot applications. We developed classification models based on Support Vector Machines (SVM) and Density-Based Spatial Clustering of Applications with Noise (DBSCAN), exclusively trained and evaluated on simulated data. Subsequently, we applied these models to real-world data, comparing their performance against the monoDrive dataset. The study demonstrates the feasibility of transferring models from a simulated environment to real-world applications, achieving an impressive accuracy score of 92% using only one radar sensor. This finding underscores the potential of radar sensors and simulation in the development of smart parking management systems, offering significant benefits for improving urban mobility and reducing environmental impact. The integration of radar sensors and simulation represents a promising avenue for enhancing smart parking management systems, addressing the challenges posed by the exponential growth in personal vehicle ownership. This research contributes valuable insights into the practicality of using simulated radar data in real-world applications and underscores the role of radar technology in advancing urban sustainability.

Keywords : autonomous vehicle simulator, FMCW radar sensors, occupancy detection, smart parking management, transferability of models
Conference Title : ICECS 2024 : International Conference on Electronic Circuits and Systems
Conference Location : Amsterdam, Netherlands
Conference Dates : February 05-06, 2024