Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Training Neural Networks for Collision Avoidance

Project Manager
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Project Term
2024 - 2025

Clusters
Lichtenberg II Cluster Darmstadt

Software
PyTorch

Additional Software
YOLOv8, Robot Operating System, OpenCV

Institute
Flight Systems and Automatic Control

University
Technische Universität Darmstadt

Introduction

The increased popularity of drones and unmanned aerial vehicles (UAVs) for both commercial and recreational purposes has significantly crowded the low-level airspace in urban areas. Particularly below an altitude of 150 meters, UAVs must share airspace with manned aircraft, such as rescue helicopters and future air taxis. Due to safety considerations, it is essential for UAVs to reliably detect and avoid collisions with these aircraft, especially since many of them are not equipped with cooperative positioning systems. Traditional active sensing methods like radar and lidar systems are often too heavy, expensive, or energy-consuming for widespread use on UAVs. Hence, computer vision-based systems using conventional cameras present a practical alternative. Such passive systems are lightweight and energy-efficient but require substantial computational resources. This project leverages High Performance Computing (HPC) to manage complex image processing tasks and to facilitate training and deploying sophisticated neural network models necessary for reliable detection and distance estimation of helicopters in urban airspace.

Methods

The methodological approach primarily involves computer vision techniques based on neural networks. A sophisticated detection framework was developed using a neural network model known as "You Only Look Once" (YOLO), specifically YOLOv8. This network efficiently detects objects — in this case, helicopters —

in images taken from regular color (RGB) cameras. After detection, a method to estimate the distance to these helicopters was implemented by utilizing the relationship between their apparent size (bounding box dimensions) and their actual distance. A regression approach was applied to predict the distance based on the dimensions and positions of the bounding boxes produced by YOLO. The HPC cluster was vital in training the neural network model on large datasets in the Terabyte range, enabling extensive experiments and optimization in a reasonable amount of time. This method provides a computationally effective balance between accuracy and speed, essential for real-time applications.

Results

The implemented system achieved significant outcomes during the project. The YOLO-based detection method reliably identified helicopters across various urban scenarios and lighting conditions. The distance estimation component demonstrated effective and robust performance, achieving accuracy that is sufficient for preliminary detection and avoidance scenarios. It was found that although vision-based systems alone currently cannot entirely replace traditional active systems for detect-and-avoid applications, the performance of the developed CV-based approach showed high potential. The HPC environment proved crucial in training neural networks, optimizing performance, and efficiently handling large-scale image processing tasks.

Discussion

The project demonstrated promising results in detecting and estimating the distance to helicopters using computer vision, showcasing considerable potential for passive detect-and-avoid systems in urban airspace management. The detection accuracy and speed reached levels suitable for practical UAV applications, although further improvements and validation are required to increase reliability under diverse environmental conditions. Future research should focus on enhancing model accuracy through larger and more diverse training datasets that have to include precise labeling even at large distances, optimizing computational efficiency, and integrating additional sensors for redundancy and improved reliability. Also, future studies should investigate how to effectively combine vision-based systems with other passive and active sensing technologies to build comprehensive detect-and-avoid systems.

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