Non-cooperative UAV Detection: A Deep Learning Approach Using LiDAR and Camera Data

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ABSTRACT

The widespread use of unmanned aerial systems (UAS) has raised concerns regarding their ability to threat critical infrastructure and other aircraft, motivating the development of counter UAS systems (cUAS). cUAS solutions are only as effective as their capability to detect and track threatening aircraft, which must be achieved accurately within a limited time frame. One potential detection solution for c-UAS application is the light detection and ranging (LiDAR) sensor, that can directly measure object distances at high frequencies (i.e., up to 20Hz) and scan targets within a 360° field-of-view (FOV). However, LiDAR sensors produce sparse measurements that prevent the identification and classification of micro unmanned aerial vehicles (UAVs). Inversely, electro-optical (EO) cameras can perceive the environment at a higher resolution, but lack the capability of direct distance measurement. To implement any sensor fusion technique, data from distinct frames of reference needs to be correlated in a unified perspective.

This study proposes a system designed to run onboard a UAV capable of detecting and estimating the relative position of encountered non-cooperative UAVs. The system utilizes both LiDAR (Light Detection and Ranging) measurements and images from a camera to detect and track nearby UAVs using a deep learning approach. Instead of manually labelling a dataset to train the chosen object detector - YOLO (You Only Look Once), synthesized images were automatically created and annotated using the open-source software AirSim. YOLO was trained with 4761 training and 530 validation images to which presented a mAP (Mean Average Precision) of 99:03%, precision of 98%, recall of 98% and an IoU (Intersection over Union) of 83:11%. YOLO outputs bounding box coordinates that are combined with measurements given by the LiDAR to estimate the relative position of the encountered UAVs. Kalman Filtering is used to smooth the obtained estimations. The system can be used in situations where conventional localization systems are not a good solution, such as sense and avoid. Simulations performed with AirSim presented a maximum RMSE (Root-Mean Squared Error) of 8:60m for the distance estimation with a camera with a 720p resolution and 7:80m for a camera with 1080p, when the UAV is at a distance of 50m. When tested in the simulation images, YOLO presented a precision of 100% and the lowest recall value of 92%. Finally, simulations with two UAVs were performed to confirm that the system works for any number of encountered UAVs without any a priori information or assumption.