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Drones and Airports: Radar you’re worried or not.

Drones simultaneously bring great opportunity and potential danger to modern life. Ranged detection solutions ensure security awareness in areas most at risk of major incidents, such as airports or stadiums, but small drones push the limits of the performance of these sensors. This project aims to understand the biggest challenges to remote detection of drone targets, and to provide technical contributions to improve the reliability and reduce the cost of defending sensitive airspaces for drones. Radar is an outstanding option as it can operate day-or-night, in most weather and is highly flexible in its implementation, able to operation either over multiple kilometres of range, or alternatively over smaller areas with distributed smaller sensors with a significant cost reduction. Radar has been used for a century as a ranged detection and identification tool in war and navigation, and now it is being utilised to detect, track and classify drones in military and civilian contexts. Counter-drone radar systems are installed at various airports in Britain and worldwide (Heathrow, Charles de Gaulle, Schiphol) after high-profile incursions, with many companies (Thales-Aveillant, Robin Radar, Leonardo) offering these services. The challenge of these pursuits is the existence of birds – that are very similar to drones in their size and airspace presence. My research aims to improve the classification of small, detected targets to be benign bird or unexpected drone presence.

Modern radar measures the speed of the environment. Moving targets are separated from the stationary background of the ground and buildings, and the detail of their velocity profile is available for scrutiny to fuel robust classification. Drones additionally have spinning propellors that can be detected by a radar, and this provides strong evidence that the target is a drone. Even fixed winged drones possess spinning motor blades to provide propulsion which cannot be fully obscured. Small drones with very small propellors may not be detectable, so not always can this feature be relied upon for classification. Larger targets such as ground vehicles, manned aircraft, helicopters etc., are a simple matter to classify for a present-day radar system. This research project provides a significant contribution to aid the exploitation of propellor returns for classification, as well as with consideration when they are not present.

This project began in September 2020 as a PhD at the University of Birmingham (UoB) primarily supported by the Future Aviation Security Solutions (FASS) programme by Department for Transport with Connected Places Catapult. Aveillant (now part of Thales organisation) is counter-drone radar manufacturer's CTO Stephen Harman was the industrial sponsor. Dr. Mohammed Jahangir (formerly of Aveillant) is the primary supervisor with Dr. Michail Antoniou and Prof. Chris Baker also providing great experience and assistance. Two Aveillant radar systems with up to 10km operating range were installed on the UoB campus partially overlooking the densely urban Birmingham city centre, providing a challenging operational environment compared to e.g., a relatively empty field. These real radar systems allow the collection of real, operationally realistic data from which research developments can be examined in a real scenario, allowing a validation of findings that brings a real significance to this project.

With a personal background in experimental and theoretical physics from an MSci undergraduate from UoB, and desire to engage with physical hardware and machine learning, this project provided a great opportunity for me to test my fundamental skills and learn new capabilities in field new to me. I have always been interested in difficult challenges and this PhD project has been a great experience in both the subject matter and application areas. To study an emergent technology such as drones was an exciting opportunity, and it has been insightful to get to grips with their operation and also the considerations to countering them. Reading of the drone incursions that have occurred at airports worldwide has been particularly relevant to myself as a frequent flyer with my family home across the Irish sea.

The project began with the installation of the two radar systems in the first two years, the collection and analysis of real data from the first 3 months, the development of simulation approaches from then for the next 1.5 years and for the last 2 years the building and validation of novel deep learning approaches.

Radar data is less available than camera images or written text, of which the latter has seen huge development in machine learning capabilities. Efforts to collecting huge amounts of radar data are slow, so the creation of synthetic drone radar data is of much interest. Utilizing real motor speed recordings was done for the first time in this work, which have been shared in radar conference and journal publications, on the way celebrated by achieving 3rd place in the student paper competition at the IEEE New York Radar Conference 2021.

Evaluation of the above synthetic data approach was conducted with the installed radar systems, difficult environment, and real varied bird and drone targets with modern machine learning approaches has been recently shared in IEEE Transactions on Radar Systems. Work is progressing to further show the process value of the approach found in this work.

What the project has demonstrated through its publications is that radar sensors can be engineered to have a robust classification of drone targets of interest from potentially confusing bird presence. The simulated data approach will allow algorithm designers to develop classifiers overcoming the limitation of lack of data for deep learning.

The drone's motor speeds and their significance in radar data is a route to further, more elaborate processing that should be able to extract more intelligent information from the drone, such as, in (my opinion of the) order of decreasing likelihood: number of propellors, fault detection, drone mass, flight operation i.e. manually via controller or automatically via computer and intention prediction. Simulation of drone flights will enable profiles to be considered from drones that don't even exist yet.

I believe that radar is presently, and with further research, development and business initiative will become an even greater sensor for cost effective, robust, low profile detection and reporting of drones in areas of interest. Radar systems also hold the potential to provide other outputs of interest to human and environmental factors, such as bird flock monitoring around airports and long-term trends of bird activity.