**EPSRC DLA PhD Studentships**

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**Section 2 – *Project Information***

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| **Project Title** | **Model predictive electric UAV guidance using wind measurements and forecasts for coverage path planning missions** |
| **Project Summary** | |
| Uncrewed aerial vehicles (UAVs) have significantly evolved in terms of efficiency and safety but some of their applications such as precision agriculture and package delivery have not progressed as fast as anticipated. This is partly due to UAV safety concerns when deployed at scale and the fact that weather is still too often a factor in UAV accidents as in the case of multiple delivery and even military UAV crashes. Wind rejection is still predominantly performed using conservative robust control or wind disturbance compensation, which can lead to inefficiencies, such as the compensation of wind effects when they are beneficial. Exploiting recent advances in control such as wind preview to improve the wind handling can not only enhance energy efficiency but also UAV safety.  This funded PhD project at University of Leicester therefore aims for the development of wind-resilient autonomous UAV control algorithms, using wind estimation and wind preview (forecasts) together with some of the latest advances in the control of small UAV. You will be working with Dr Nadjim Horri and Dr Emmanuel Prempain from the School of Engineering, who have a track record in the guidance, navigation and control of UAVs. This project will be supported and co-supervised by Flare Bright Ltd, a company at the forefront of UAV innovation, including but not limited to UAV navigation and resilience. The project aligns with the environment and data analytics research themes at the College of Science and Engineering and with the aerospace control theme of the Aerospace Research Group at the School of Engineering.  In this project, algorithms will be developed to use wind estimation/measurements and wind forecasts to maintain a safe and efficient UAV operation in the presence of wind gusts and turbulence. UAV guidance algorithms will be developed to enhance the safety, energy and tracking efficiency of small electric fixed-wing UAV with coverage path planning (CPP) missions, such as agricultural land surveys.  The research will first be focused on the optimisation of back-and-forth CPP trajectories for area coverage in a wind field, which will be obtained from simulated local wind speed and direction measurements and forecasts. Different scenarios will be considered for the designated area to be covered by the UAV and CPP parameters and the aim will be to propose paths that reduce energy consumption for these missions, given wind speeds and directions.  Path following algorithms will then be designed to determine the attitude and speed guidance commands required to accurately track the desired trajectories, while balancing energy consumption with wind disturbance rejection and tracking accuracy. The focus of the control will be on this guidance outer loop, assuming that conventional control is available for the inner loop attitude and speed controllers. UAV dynamical models will be developed by including the wind effects, which will be applied using Dryden models or equivalent. State-of-the-art path following algorithms including carrot chasing and other line of sight algorithms [1] where the UAV is controlled to point the velocity vector to a moving target on the desired trajectory will be considered to maintain robustness to disturbances either using a robust auto-tuning methodology or by compensating an estimated/measured wind disturbance.  A computationally efficient model predictive control (MPC) approach [2], [3] will then be developed to incorporate wind forecasts and measurements in the optimised path following. Model predictive control optimises a trade-off between trajectory tracking and energy efficiency over a shifting prediction horizon, with the ability to handle input and output constraints. A simulation analysis will allow to evaluate the extent to which this approach further enhances flight safety, energy consumption and tracking accuracy depending on the UAV mission scenario. Hardware-in-the-loop (HIL) simulations of the path following controllers including MPC will be performed for 2D (constant altitude) then 3D scenarios, from take-off to landing and using CPP missions under realistic wind conditions at different turbulence levels.  For any technical questions on this research project, please contact Dr Nadjim Horri (nmh22@leicester.ac.uk). | |
| **References** | |
| [1]. Sujit, P.B., Saripalli, S., Sousa, J.B. Unmanned Aerial Vehicle Path Following: A Survey and Analysis of Algorithms for Fixed-Wing Unmanned Aerial Vehicless, IEEE Control Systems Magazine, vol. 34, no. 1, pp. 42-59, Feb. 2014, doi: 10.1109/MCS.2013.2287568.  [2]. Mendez, A.P.; Whidborne, J.F., Chen, L. Wind Preview-Based Model Predictive Control of Multi-Rotor UAVs Using LiDAR. Sensors 2023, vol. 23, no. 3711, [doi: 10.3390/s23073711](https://doi.org/10.3390/s23073711).  [3]. Dong, Z., Jiang, J., Liu, C., Coombes, M., Chen, W-H. Economic Model-Predictive Control for Aircraft Forced Landing: Framework and Two-Level Implementation, IEEE Transactions on Aerospace and Electronic Systems, vol. 58, no. 2, pp. 1119-1132, April 2022, doi: 10.1109/TAES.2021.3117376. | |