Modelling of critical weather flight performance of multi-copter UAV for increased resilience controller design.

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Aircraft icing has been identified as a major safety issue for manned urban air mobility (UAM) and unmanned aerial vehicles (UAV) likewise [1]. Restrictions imposed by the manufacturers and/or legislators regarding a UAV's tolerance to adverse weather conditions can reduce the availability. For UAV without specific adverse weather protection measures, the availability for legal flight is reduced even below 30% in the cold season for most regions of the world and is below 85% in the cold season in regions beyond 45°N or −45°S even for drones with enhanced weather resistance [2]. Emergency organizations experience a reduction in their operational capability as a result.

Figure 1: The 25 kg multi-copter UAV in the climatic wind tunnel.

To research on the capabilities of weather modelling and to increase accuracy of weather radar measurement interpretation, the collaborative research project IFIRE (**I**cing **F**orecast **I**n **R**eal **E**nvironment) is carried out [3]. To improve weather forecast models and calibrate data gathered from radar data, flight into known icing condition is intended to be performed in confined airspaces. These test flights are performed with a multi-copter UAV with a takeoff mass of up to 25 kg (shown in Fig. 1) equipped with specialized sensors for measurement of e.g. liquid water content (LWC) and droplet size.

Figure 2: Severe ice accretion on a multi-copter propeller

Therefore, we aim at identifying prerequisites to ensure safe operation of multi-copter UAV under adverse weather conditions as a significant ice-accretion can occur within several minutes of operation (see Fig. 2). Developing flight controllers capable of handling degraded flight performance requires a simulation model for ice accretion and performance degradation under icing condition on a powertrain for the UAV intended for flight experiments as the influence on lift and drag can be dramatical (see Fig. 3)
Data are gathered at test campaigns for varying icing conditions within the CS25, Appendix C envelope in a climatic wind tunnel. A data driven approach (Dynamic decomposition with Control, DMDc [4]) is chosen for system identification. The high-fidelity simulation model allows future extension of UAV controller design for the flight under adverse weather conditions.

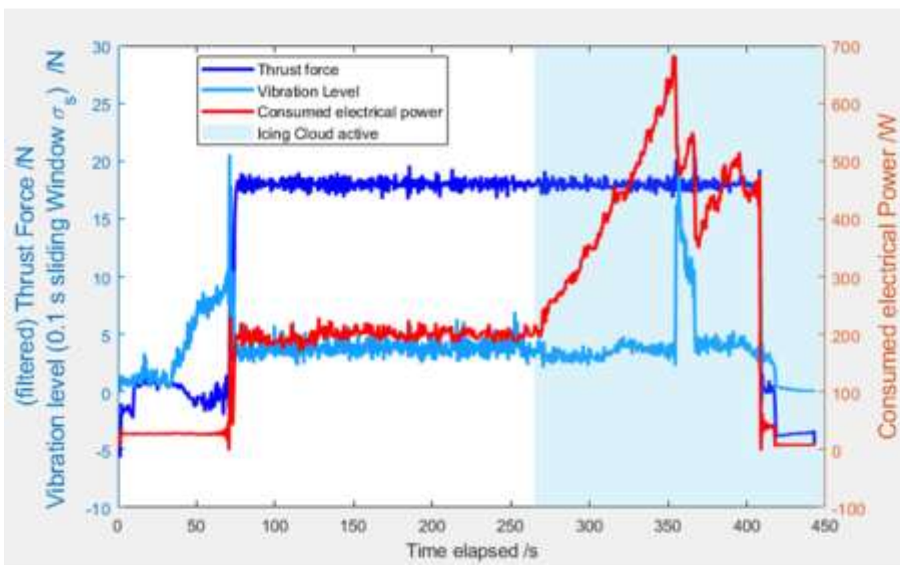

Figure 3: Increase of required electrical power to maintain the thrust force required to maintain cruise flight of the 25kg UAV under severe icing conditions.

It has been shown that commercially available UAV controllers are not fully capable of handling the challenges of degraded performance and increased time constants and inertia of ice accretion on the lift generating propellers in the flight regime they cover [5]. The current work investigates on limitations of conventional flight control methods such as full state feedback controller designed with LQR for various operating points such as hover flight or cruise flight. To overcome strongly varying operation points resulting from ice accretion on the propeller, gain scheduling can be implemented for various ice mass accreted on the propeller. This requires accurate knowledge of the ice mass currently on the propeller, that we achieve trough analysis of fight performance data. A long-short-term-memory (LSTM) neural network is used to estimate the ice mass on the propeller and thus allows for selection of an appropriate gain parameter set. The LSTM model has shown to be capable of estimating the ice mass based solely on performance data (e.g. commanded thrust, RPM, consumed electrical Power) of a drive train [6].

We propose gain scheduling of controller gains adopted to the ice mass on the propeller estimated by interpretation of performance data. We show simulation results and show up a pathway to enhance resilience and safety margins for operation of UAM in adverse weather conditions.

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Biography

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A. Fallast is a researcher and senior lecturer at the Institute of Aviation at the University of Applied Sciences, Graz where he leads the research Group “Intelligent Systems”. He is a PhD Student at the Technical University Graz (Institute of Machine Learning and Neural Computation) researching Machine Learning methods for anomaly detection and data driven modelling.
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