Safe and Efficient Arrival of eVTOLs in On-Demand Urban Air Mobility

The electric vertical takeoff and landing (eVTOL) aircraft can alleviate transportation congestion on the ground by utilizing three-dimensional airspace efficiently. However, the endurance (specific energy) of Lithium-ion Polymer (Li-Po) batteries imposes severe constraints on the operational time span of an eVTOL on urban air mobility (UAM) passenger transportation mission.

The first part of the research focuses on the generation of energy efficient trajectories of eVTOLs with the required times of arrival (RTA)s. The problem formulations are performed in multiphase optimal control framework with energy as the performance index for the following eVTOL aircraft types: (i) multirotor and (ii) tandem tilt-wing. These two types of eVTOLs were chosen because of their performance characteristics falling at two extremes of the performance spectrum of eVTOLs. The proposed multiphase optimal control problem formulations and the corresponding numerical solutions enable an eVTOL aircraft to meet the given RTA and achieve the most energy efficient arrival trajectory, which is a critical enabler for the safe and efficient future eVTOL operations for passenger transportation and cargo delivery in UAM environment. The problem formulations are validated in a UAM passenger transport use cases with (i) EHang 184, (ii) Airbus Vahana, and (iii) the Uber Elevate proposed vertiport concept in numerical simulations.

The second part of the research involves sequencing and scheduling problem for a mixed fleet (winged/wingless) of eVTOLs scheduled to land on a vertiport with single landing slot in UAM. The objective of the problem is to minimize the makespan (landing completion time) of a given set of eVTOLs, which is equivalent to maximizing the arrival throughput. The landing order (sequence) and makespan of the mixed fleet is optimized using a heuristic approach called insertion and local search (ILS) combined with two different scheduling methods i) mixed-integer linear programming (MILP) or ii) time-advance (TA) algorithm. Finally, sensitivity analysis is performed to see the impact of the number of eVTOLs expected to land on computational times of both the algorithms. Through numerical simulations and sensitivity analysis, our algorithms demonstrated real-time scheduling capabilities for on-demand UAM arrivals, which can be used as a potential future service for UAM vertiports and terminal airspace.

Keywords: Electric Vertical Takeoff and Landing (eVTOL), Estimated Time of Arrival (ETA), Insertion and Local Search (ILS), Mixed Integer Linear Programming (MILP), Required Time of Arrival (RTA), Urban Air Mobility (UAM).