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EDITED AND REVIEWED BY
Ramesh K. Agarwal,
Washington University in St. Louis,
United States

*CORRESPONDENCE
Krishna M. Kalyanam,
krishna.m.kalyanam@nasa.gov

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Editorial: Enabling technologies for advanced air mobility

Krishna M. Kalyanam[1]* and Kelly Cohen[2]

[1]Aviation Systems Division, NASA Ames Research Center, Moffett Field, CA, United States, [2]Department of Aerospace Engineering, University of Cincinnati, Cincinnati, OH, United States

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Editorial on the Research Topic
Enabling technologies for advanced air mobility

1 Introduction

This Research Topic was formulated to address some of the fundamental barriers that must be overcome to enable Advanced Air Mobility (AAM) operations at scale. The Federal Aviation Administration (FAA) plans to open up the skies with a vision to allow both manned and unmanned vehicles to operate together safely in a mixed-use airspace. This vision requires careful separation of air corridors and negotiated rules for conflict resolution between manned and unmanned aircraft. Current rules regarding conflict detection and resolution between manned aircraft are highly regulated and typically managed by (air traffic) controllers on the ground. To continue the high levels of safety we currently enjoy, we need self-regulating unmanned aircraft that can follow established "rules of the road" and ensure that they stay well separated from other aircraft and critical infrastructure on the ground. This is particularly challenging given that it is unreasonable to expect controllers to manage the growing number of unmanned aircraft. So, we need to move towards a different framework, where unmanned aircraft for the most part are self organized (e.g., into cohesive platoons), detect and avoid obstacles (both in the air and on the ground) and can also negotiate and resolve conflicts with other aircraft autonomously with minimal human oversight. In addition, current Air Traffic Management (ATM) concepts are also human-centric in that they assume verbal communication and coordination between pilots and controllers. This notion cannot be extended to unmanned aircraft with no pilots on board.

With the emergence of fast on-board computation and real-time decision making capabilities in unmanned aircraft systems (UASs), we can utilize state of the art route generation (and path planning) algorithms that, e.g., enable detection and avoidance of dynamic obstacles. This is particularly relevant for GPS-denied or sparse GPS environments, where advanced sensing and navigation algorithms are required for vehicles to fly autonomously. In this volume, we present five papers that investigate and present some of the highlighted enabling technologies and methodologies for Advanced Air Mobility operations. In particular, the Research Topic focuses on key research advances in the areas of inter-vehicle conflict detection (Wells and Kumar), dynamic obstacle avoidance (Cortez et al.), path planning (in the presence of wind and other weather phenomena) (Pradeep et al.), vehicle platooning (Mayle and Sharma) and traffic management protocols for AAM vehicles (Chin et al.).

2 Papers in the Research Topic

Pradeep et al. quantify the operational benefits (energy and time savings) of flying wind-optimal lateral trajectories for short UAS flights in an urban environment. The research study suggests that for short flights in an urban environment, operational benefits of the wind-optimal lateral trajectories over the corresponding great-circle (shortest path) trajectories depend on the: i) wind field's spatial variability, ii) wind magnitude and direction relative to flight path, and iii) cruise segment length. The authors show that up to 2 min of cruise flight duration savings can be achieved, which is significant for rapid delivery of goods and services in an urban environment.

Cortez et al. consider path planning of turn-rate constrained (or fixed wing) UAS that avoid dynamic obstacles and limits cumulative damage to the vehicle, e.g., when it flies through a hazardous environment. As an exemplar, they consider changing icy conditions as a dynamic obstacle that needs to be avoided. They employ a Dynamic mode decomposition (DMD) technique to learn and predict icy conditions at flight level and propagate the growing (or shrinking) obstacle boundaries. Using a recently developed scalable backtracking hybrid A* graph search algorithm, the authors compute flyable paths for the vehicle in the presence of path dependent integral constraints and dynamic obstacles.

Wells and Kumar present a conflict detection system for small Unmanned Aerial Vehicles (sUAS), composed of an interacting multiple model state predictor and a Haversine-distance based conflict detector. The interacting multiple model state predictor runs on a ground-based system and only has access to current vehicle positional information. Position estimates of vehicles in the near future are computed by a Kalman filter based state predictor. Potential conflicts between vehicles based on future position predictions are detected using an Haversine distance-based conflict detection algorithms. The results of the combined prediction and conflict detection algorithms are illustrated in a ROS-Gazebo simulation environment for mid-air conflict detection involving 10 sUAS operating in a confined airspace.

Mayle and Sharma present a novel control technique based on missile guidance law for platooning of small UAS in congested air corridors. The position of all agents within a platoon are estimated by cooperative localization techniques and a controller is designed such that a velocity command is followed and the desired inter-vehicle separation distance is maintained. The authors provide a stability analysis of the controller with supporting phase potraits. The paper develops a centralized Extended Kalman Filter (EKF) approach to estimate the joint state vector that comprises of positions, velocities, attitudes, and other states by exchanging measurement data between vehicles (i.e., to perform cooperative localization). This is shown to be effective particularly in environments with degraded GPS signals. The authors show via simulation that 12 platoons with 8 – 10 agents follow a desired path and avoid collisions even with limited sensing range for two different airspace structures.

Lastly, Chin et al. propose development of a new traffic management algorithm for advanced air mobility. The paper explores the use of traffic management protocols ("rules-of-the-road" for airspace access) to enable efficient and fair operations. The authors design and analyze a cost aware congestion management protocol for AAM with the following attributes: 1) gridlock avoidance, 2) efficient sector deconfliction, and 3) conflict management via price based auctions. The authors show that it is possible to avoid gridlock and improve efficiency by leveraging the concepts of cycle detection and backpressure. Using simulations of representative advanced air mobility scenarios with 100s of flights, they demonstrate that the proposed traffic management protocol can help balance efficiency and fairness, in the context of both operations and economics.

3 Concluding remarks

There is a lot of research activity around emerging concepts for Unmanned Aircraft Systems Traffic Management (UTM) and towards establishing "rules of the road" for manned-unmanned interactions. In this volume, we provide scalable solution methods to enable some key components of a future AAM ecosystem and show how they are implementable under real-world scenarios. We hope that this volume will provide a fresh impetus to finding solutions to the hard problems in enabling Advanced Air Mobility (AAM) operations at scale.

Author contributions

KK: Writing–original draft. KC: Writing–review and editing.

Conflict of interest

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