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Editorial

Special Issue on Development of Autonomous Unmanned Aerial Vehicles

In support of military operations and civil applications, the Unmanned Aerial Vehicles (UAVs) have quickly emerged as useful and versatile tools with extensive scope of mission profiles. Examples range from small-sized UAVs like Wasp and Black Widow, to medium-sized UAVs like Pioneer and RMAX, to large-sized UAVs like Global Hawk and A160. Flying platforms vary from fixed-wing, rotary-wing, flapping wing, or a hybrid of various concepts. Their missions include but no limited to surveillance, reconnaissance, target acquisition, datalink relay, sensor shooting, border patrol, and highway monitoring.

Operating environments play an important role in formulating design features. In particular, challenges involving operations in the urban settings may include hostile environments, loss of line-of-sight, poor GPS reception, fast maneuver in narrow urban corridors, perch and stare, and even flying into the buildings. On the other hand, UAVs for naval applications may require VTOL (Vertical Take-Off and Landing) capability, extended payload capacity, longer range, and operating under various sea conditions. These challenges in turn affect the design of autonomous control system.

Classical features of autonomous control design involve stability enhancement and waypoint flight. However, new requirements in the recent development of UAVs demand robust and adaptive control techniques for various flight conditions, aggressive maneuvers, non-traditional sensor selections like cameras, obstacle avoidance, fault detection and tolerance, power management for perch and stare, team formation and coordinate flight. In order to achieve these ambitious requirements, a systematic and innovative thinking needs to be in place. Moreover, concerted efforts are critical on issues related to practical implementation.

The aim of this special issue is to bring together researchers and practitioners in the fields of unmanned systems, with a common interest in the new challenges in platform design and autonomous control development. We hope to attract contributions on novel ideas in the design of non-conventional UAVs, autonomous control, navigation, guidance, and implementation considerations such as miniature flight computer and computational efficiency.

In this special issue, two papers are dedicated to design of unconventional and micro UAVs. First, Bermes et al. propose design of two prototypes of autonomous micro helicopter muFly. Rotor configuration and steering selection criteria are discussed in details. Adopting a coaxial configuration with a swashplate steering from the lower rotor, these prototypes are built and flown in untethered test flights. The second paper by Andersh et al. describes development and integration of an UAV. Choice of flying platform, onboard electronics and sensing unit, and system integration are carefully elaborated. An overview of ongoing tele-operation research is offered at the end of the paper.

This special issue also puts forward three papers on UAV stabilization, autonomous flight, and intelligence control. First, Paw et al. provide an integrated framework for small UAV flight control development. A set of design tools is given to enable control engineers to rapidly synthesize, analyze and validate a candidate controller design. Next, Cai et al. conduct design and implementation of a robust and nonlinear automatic flight control system for an unmanned helicopter. With nonlinear modeling, a three-layer control architecture is proposed, which includes an inner-loop controller for internal stabilization, outer-loop controller for position and heading, and a flight-scheduler for flight missions coordination. As showcased in actual flight tests, the resultant unmanned helicopter is capable of achieving high performance in accordance with military standard. The third paper by Lei et al. presents a composite control method for the UAV operating in polar extreme environment. Based on vector field and linear quadratic regulator control, a small UAV can realize precise trajectory following under strong wind disturbance. Experimental flight results indicate that the unmanned vehicle is able to achieve high trajectory following in the polar environment.

In addition, this special issue gathers two papers on road and terrain following. Egbert et al. address the problem of autonomously maneuvering a miniature air vehicle to follow a road. With a camera as primary guidance sensor, the road is identified using HSV classification, flood-fill operations, and connected component analysis. The paper focuses on derivation of explicit roll-angle and altitude-above-ground-level constraints to guarantee the road remains in the footprint of the camera. The effectiveness of the approach is demonstrated through simulation and flight tests. The second paper by Samar et al. investigates autonomous terrain following for an UAV. A terrain-following algorithm is designed to construct a smooth reference trajectory using waypoints for climb and descent. This is followed by onboard controller for altitude tracing and stability augmentation of the vehicle. Resultant guidance and control scheme is implemented and validated in flight trials.

Finally, there are three papers focusing on path planning. Moon et al. argue the needs for an integrated approach to combine path planning for obstacle avoidance with envelope protection. This is to ensure operational safety for an UAV while maneuvering in obstacle rich environments. Both obstacle avoidance and envelope protection are treated as inequality constraints in a state space formulation. Their method is evaluated through nonlinear simulation. The second paper by Chen et al. considers the coverage path of UAVs in a polygon area with an enhanced exact cellular decomposition method. The paper explores turning motion of UAVs and

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transformation of convex polygon, and develops a minimal sum of widths decomposition algorithm. A third paper by Karimoddini et al. presents a new approach of hybrid supervisory control of the UAVs for a two dimensional leader follower formation scenario. Abstraction based on polar partitioning of the state space is introduced. This is followed by a modular decentralized supervisor in the path planner level of the UAVs to achieve both formation reaching and formation keeping.

Development of autonomous unmanned aerial vehicles has attracted great attention in the last few decades. While this special issue has covered many areas in the field, these and many other topics, like air refueling and ship deck operations, are continuously evolving and certainly worth future discussion.

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