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Editorial

Introduction to the special issue on aerial robotics

Aerial robotics has been an active area of research for several decades. It has been steadily maturing throughout the years leading to sophisticated auto-pilot systems for manned vehicles and fully autonomous flight and navigation systems for a range of military and civil applications. Nowadays, the emergence of modern embedded computing, sophisticated GPS positioning and the availability of low cost MEMS sensor systems, along with a growing hobby market in low-cost lightweight remote controlled aerial vehicles has opened a vast range of new civil and military applications. The commercial landscape of aerial robotics is characterized by a plethora of small start-up companies marketing specialized platforms for specific applications. The growth in commercial interest has in turn fueled significant growth in research effort in the field of aerial robotics, particularly in the systems and control community. Many of the practical challenges associated with real time implementation of control and estimation algorithms for aerial robotic vehicles are yet to be satisfactorily resolved.

Aerial robotic vehicles have complex and poorly known dynamic models. The sensor systems used can be noisy and poorly characterized. The applications considered may require them to be flown closer to the vehicle performance limitations than for manned vehicles. They are often flown in close proximity to an unknown, or only partially known, and dynamically changing physical environment. They might be designed to fly indoors or in an environment where GPS signals are not available. These practical requirements and constraints lead to a field that will benefit tremendously from the application of sophisticated control and estimation techniques. Successful control and estimation algorithms must deal with the inherently nonlinear and poorly known dynamic models of the vehicles. They should deliver global or at least semi-global stability that is robust to dynamically changing environment conditions. They must be designed with the underlying non-Euclidean nature of the state representation of a flying vehicle in mind, typically the special Euclidean group $SE(3)$ for pose control or the special orthogonal group $SO(3)$ for attitude control. They should be tailored to work naturally with the sensor systems that can be effectively mounted on an aerial vehicle and deal with the high noise levels of such sensors. Robust and nonlinear control and estimation algorithms offer the potential to significantly improve the overall performance of aerial robotic systems.

The objective of this special issue is to report some recent results in the systems and control field as it applies to aerial robotics, especially those that identify pertinent practical and theoretical open problems, as well as efficient implementations in practical applications. Among the submitted papers, 13 were selected for inclusion in this special issue after a very detailed review process. The selected papers cover a wide range of important applications in aerial robotics such as modelling, control design, attitude estimation, visual-feedback, and real-time embedded systems.

In Rakotomamonjy et al. a flight simulation model for a flapping-wing micro-aerial vehicle is presented. The model integrates the aerodynamic forces to determine the global motion of the flapping-wing vehicle. A simple nonlinear stabilizing control scheme based on a simplified model has been presented. In Pounds et al. a dynamic model of a custom-built quadrotor aircraft has been derived and simple control schemes have been implemented. The effectiveness of the system is shown through indoor and outdoor flight experiments. The work in Schafroth et al. deals with modelling, system identification and robust control design for a coaxial micro-helicopter.

In Martin and Salaün, a nonlinear attitude estimation algorithm, using measurements from low-cost inertial and magnetic sensors, has been proposed for a flying rigid body. The proposed local observer is easy to tune and is computationally efficient as shown in the real-time experiment. The paper by Minh-Duc Hua, presents a semi-global attitude observer for rigid bodies evolving in 3D-space using GPS-velocity and inertial measurements. The proposed observer is suitable for non-stationary flight applications involving relatively large linear accelerations.

In Bristeau et al., the authors deal with the design of an embedded system for state estimation and control of a small scale helicopter. Experimental results of an autonomous hovering fight have been presented. In Naldi et al. an experimental design of a small-scale vertical take-off and landing (VTOL) ducted-fan aerial vehicle is presented including flight control schemes, hardware and software architecture.

In Chao et al., the main focus of the paper is the design and implementation of a fractional PI controller for the roll angle of a small fixed-wing unmanned aerial vehicle (UAV). The fractional order PI controller is shown to outperform the optimized traditional PID controller. In Mettler et al., an autonomous guidance system based on a receding horizon optimization as well as its experimental implementation have been reported.

In Courbon et al., a vision-based navigation scheme has been proposed for a VTOL-UAV using a single embedded camera observing natural landmarks. This approach is based on a 'visual memorization' of the environment leading to a 'visual route' to the target through which the UAV is driven using an appropriate

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visual-feedback scheme that does not require any explicit trajectory planning. This strategy has been supported by experimental results on a quadrotor aircraft (x4-flyer). The work of Bisgaard et al., considers the design of a vision-based estimation and control scheme for a helicopter slung load system. Simulations and laboratory flight tests show the effectiveness of the control strategy in terms of minimizing the load swing. Huh and Shim propose a vision-based automated landing system for a UAV using a dome-shaped airbag. The key idea consists of using a coloured dome shaped airbag acting both as the recovery device and as the target to guide the UAV using visual servo control. Finally, in Yu et al. a vision-based collision avoidance strategy is proposed for miniature UAVs. Using a computer vision system and an extended Kalman filter, a navigation map is constructed, from which a collision-free path is obtained. The proposed algorithm has been tested experimentally.

We would like to express our gratitude to the authors and the reviewers for their efforts in making this special issue a success.

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