Special Issue on High-Speed Vision-Based Autonomous Navigation of UAVs

Loianno, Giuseppe ; Scaramuzza, Davide ; Kumar, Vijay

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JFR Sepcial Issue
Vision-based High Speed Autonomous Navigation of UAVs

1 Guest Editors

Giuseppe Loianno, University of Pennsylvania
Davide Scaramuzza, University of Zurich
Vijay Kumar, University of Pennsylvania

2 Editorial: Special Issue on High Speed Vision Based Autonomous Navigation of UAVs

During the last decade, the Unmanned Aerial Vehicles (UAVs) industry has experienced an exponential growth and Micro Aerial Vehicles (MAVs) are starting to play a major role in different types of missions including search and rescue, environment monitoring, security surveillance, transportation and inspection. Small scale size vehicles can be used in constrained outdoor and indoor environments and, because of the lighter weight, represent only a modest risk for people. However, for such operations, many research challenges arise.

First, GPS-based navigation may not be possible. Fully autonomous operations in cities or other dense environments require micro helicopters to fly at low altitudes, where GPS signals are often shadowed, or indoors. In addition, some of these missions typically require fast response time and, therefore, high speed operations are a key requirement. The small size and payload constraints of these vehicles only allow the use of cameras and Inertial Measurement Unit (IMU) as the main sensors. Second, the problem of designing perception action loops for high speed navigation with vision as the primary sensors offers many significant challenges. MAVs have to be able to fly autonomously, at high speed guaranteeing robust high rate state estimation for closed loop control. Third, the environment may be very cluttered and the navigation conditions may be extreme. Finally, vehicles may have to actively explore unknown environments, without external infrastructure such as GPS and motion capture systems. In this context, an integrated approach in terms of perception, mechanics, state estimation, environment reconstruction, obstacle avoidance, planning algorithms and computation is required to support operating conditions over long ranges and short times and scales.

This first special issue of the Journal of Field Robotics (JFR) on vision-based high speed autonomous navigation of UAVs aims to establish a baseline in the field of autonomous navigation of UAVs using vision and IMU as the main sensing modalities. The goal of the research reported in this special issue is to show the improvements and present the most recent state of the art to execute fast autonomous operations with MAVs. The proposed approaches will contribute to inform the community with the most recent and innovative approaches and to extend the capabilities of current and future robotic missions.

The papers, which appear in this Special Issue, are based on two very successful workshops (with over 200 attendees in each workshop) at the International Conference on Intelligent Robots and Systems (IROS) 2015 and 2016. The workshop papers' selection was conducted by a set of experts part of the workshops' program committees. Contributed and invited presentations were invited to submit a full paper version of their works. All the papers underwent the regular JFR review process. The selected papers underscore the diversity, complexity, and growing maturity of the fast autonomy navigation in the aerial robotics field. Indeed, the selected papers, cover different aspects of the fast autonomous navigation problem ranging from estimation, system identification, control, to perception, and planning.

For fast deployment, the ability for an end used to quickly deploy the robots is essential. Thus, the dynamic parameters of the MAVs needs to be identified for control via automatic procedures considering the probabilistic nature of the measurements. A new approach on this topic is covered by Burri et al. The problem of minimal sensor suites and constraints algorithms for autonomous navigation based on stereo, monocular cameras, and event based cameras is addressed by Yi et al., Florence et al., and Scheper et al. respectively. The last work proposes a fast landing strategy with closed-loop control based on the optical flow feedback generated from an event based camera. In Florence et al., a reactive obstacle avoidance approach is presented based on new efficient disparity computation approach from stereo cameras, whereas Yi et al. propose a new monocular visual inertial navigation solution for control, which concurrently generates dense maps through the use GPU. The special issue includes two papers describing the work conducted under the auspices of DARPA Fast Lightweight Autonomy (FLA) program. The first, by Escobar-Alvarez et al., describes a reactive control based on a monocular camera solution instead of a stereo one and proposes a different representation of the environment based on time to contact instead of sparse set of points cloud, as proposed in Florence et al. The second paper proposed by Mohta et al. presents a new approach to concurrently design onboard on a consumer grade CPU mapping, control, estimation, and planning strategies based on multiple heterogeneous asynchronous sensors for fast autonomous navigation in obstacle rich environments. The approach allows reaching speeds up to 8 m/s. Finally, the special issue concludes with two papers by Perez-Grau et al. and Jung et al. The first one shows the effort in the community to create reliable architectures for autonomous flight. This concept is essential for technology transfer toward industries. Our field is playing a key role in this context since the impact of the technology on the market is evaluated to be on the order of billions of dollars. The second work is a report and it shows the key effort within our community to promote the education and outreach programs pushing new students to become familiar with the aerial robotic technology. The community is trying to disseminate new approaches in the current society challenging students to propose new solution to real problems during conferences. The work presents the research challenges of the IROS 2016 autonomous drone competition and the solutions proposed by one of the teams. The competition considered the problem of autonomous

navigation of small scale aerial platforms through a set of obstacles (colored windows) in an arena setting.

The success of the special issue is highly dependent ion the quality of the research reported in the submissions. We thank all of the authors who present their work in this special issue and contributed to its success and quality. Our special gratitude goes to our reviewers for their patience, thoroughness and dedication, and to Sanjiv Singh and Sanae Minick for advice and organization.

Giuseppe Loianno, University of Pennsylvania
Davide Scaramuzza, University of Zurich
Vijay Kumar, University of Pennsylvania