electronics

*Editorial*

# Unmanned Aircraft Systems with Autonomous Navigation

**Umberto Papa**

Department of Science and Technology, Parthenope University of Naples, 80143 Naples, Italy; umberto.papa@collaboratore.uniparthenope.it

## 1. Introduction

Unmanned aerial systems play an increasingly remarkable role in widely diffused application fields, from military defense programs and strategies to civil and commercial utilization. UAS are usually involved in dull, dirty, and dangerous (DDD) scenarios, which require reliable, extended-capability, easy-to-use, and cost-effective fixed-wing or rotary-wing platforms. Therefore, it is important to provide onboard systems capable of recognizing the environment around the aerial vehicle, detecting and avoiding obstacles, implementing path planning and management strategies, defining safe landing areas, and achieving full autonomy, especially for BVLOS (beyond visual line-of-sight) missions. The technical and economic challenges implied by the issues related to autonomous navigation range from hardware (sensors, platforms, controllers, etc.) to software (data processing and filtering techniques, optimal control, state estimation, innovative algorithms, etc.), and from modeling to practical realizations.

The aim of this Special Issue is to seek high-quality contributions that highlight novel research results and emerging applications, addressing recent breakthroughs in UAS autonomous navigation and related fields, such as flight mechanics and control, structural design, sensor design, etc.

The topics of interest are as follows:

- Two-dimensional and three-dimensional mapping, target detection, and obstacle avoidance;
- The active perception of targets in cluttered environments (foliage, forests, etc.);
- Vision-based and optical flow techniques;
- Sensors and sensor fusion techniques;
- Design models for guidance and controlled flight;
- State estimation, data analysis and filtering techniques (KF, EKF, particle filtering, fuzzy logic, etc.);
- Path planning and path management;
- Optimal control and strategies (neural networks, fuzzy logic, reinforcement learning, evolutionary and genetic algorithms, AI, etc.);
- Navigation in GPS-denied environments;
- Autolanding and safe landing area definition (SLAD);
- Environmental effects on UAVs (wind, etc.);
- Autonomous UAV or MAV swarms, and distributed architectures;
- BVLOS autonomous navigation.

## 2. Review Papers

Isaac S. Leal et al. [1] present a comprehensive approach for the dynamic modeling, control system design, simulation, and optimization of a quadcopter. The main objective is to study the behavior of different controllers when the model is working under linear and/or non-linear conditions, and, therefore, to define the possible limitations of the controllers. Five different control systems are proposed to improve the control performance, mainly the stability of the system. Additionally, a path simulator was also developed with



**Citation:** Papa, U. Unmanned Aircraft Systems with Autonomous Navigation. *Electronics* **2023**, *12*, 1591. https://doi.org/10.3390/electronics12071591

Received: 14 March 2023
Accepted: 18 March 2023
Published: 28 March 2023

the intention of describing the vehicle's movements and hence to detect faults intuitively. The proposed PID and fuzzy-PD control systems showed promising responses to the tests which were carried out. The results indicated the limits of the PID controller over non-linear conditions, and the effectiveness of the controllers was enhanced by the implementation of a genetic algorithm to autotune the controllers in order to adapt to changing conditions.

Ariante G. et al. [2] propose a practical method for the estimation of true and calibrated airspeed, angle of attack (AOA), and angle of sideslip (AOS) for small unmanned aerial vehicles (UAVs, up to 20 kg mass, 1200 ft altitude above ground level, and airspeed of up to 100 knots) or light aircraft, for which weight, size, cost, and power-consumption requirements do not allow solutions used in large airplanes (typically, arrays of multi-hole Pitot probes). The sensors used in this research were a static and dynamic pressure sensor ("micro-Pitot tube" MPX2010DP differential pressure sensor) and a 10 degrees of freedom (DoF) inertial measurement unit (IMU) for attitude determination. Kalman and complementary filtering were applied for measurement noise removal and data fusion, respectively, achieving the global exponential stability of the estimation error. The methodology was tested using experimental data from a prototype of the devised sensor suite, in various indoor-acquisition campaigns and laboratory tests under controlled conditions. AOA and AOS estimates were validated via a correlation between the AOA measured by the micro-Pitot and vertical accelerometer measurements, since lift force can be modeled as a linear function of AOA in normal flight. The results confirmed the validity of the proposed approach, which could have interesting applications in energy-harvesting techniques.

Zhang R. et al. [3] propose in their paper a novel hybrid-driven fixed-wing UAV maneuver optimization framework, inspired by apprenticeship learning and nonlinear programing approaches. The work consists of two main aspects: (1) identifying the model parameters for a certain fixed-wing UAV based on the demonstrated flight data performed by human pilot. Then, the features of the maneuvers can be described by the positional/attitude/compound key frames. Eventually, each of the maneuvers can be decomposed into several motion primitives. Formulating the maneuver planning issue into a minimum-time optimization problem, a novel nonlinear programming algorithm was developed, which was unnecessary to determine the exact time for the UAV to pass by the key frames. The simulation results illustrate the effectiveness of the proposed framework in several scenarios, as both the preservation of geometric features and the minimization of maneuver times were ensured.

Nguyen L.V. et al. [4] present a novel iterative learning sliding mode controller (ILSMC) that can be applied to the trajectory tracking of quadrotor unmanned aerial vehicles (UAVs) subject to model uncertainties and external disturbances. Here, the proposed ILSMC is integrated in the outer loop of a controlled system. The control development, conducted in the discrete-time domain, does not require a priori information of the disturbance to be bound as with conventional SMC techniques. It only involves an equivalent control term for the desired dynamics in the closed loop and an iterative learning term to drive the system state toward the sliding surface to maintain a robust performance. By learning from previous iterations, the ILSMC can yield a very accurate tracking performance when a sliding mode is induced without control chattering. The design is then applied to the attitude control of a 3DR Solo UAV with a built-in PID controller. The simulation results and experimental validation with real-time data demonstrate the advantages of the proposed control scheme over the existing techniques.

Lerro A. et al. [5] in their paper aimed to describe the verification in a relevant environment of a physics-based approach using a dedicated technological demonstrator. The flow angle synthetic solution is based on a model-free, or physics-based, scheme and, therefore, it is applicable to any flying body. The demonstrator also encompasses physical sensors that provide all the necessary inputs to the synthetic sensors to estimate the angle-of-attack and the angle-of-sideslip. The uncertainty budgets of the physical sensors are evaluated to corrupt the flight simulator data with the aim of reproducing a realistic scenario to verify the synthetic sensors. The proposed approach for the flow angle estimation is suitable for modern and future aircraft, such as drones and urban mobility air vehicles. The results presented in this work show that the proposed approach can be effective in relevant scenarios, even though some limitations can arise.

Song Y. et al. [6] propose a two-way neighbor discovery algorithm based on a spatial multi-channel through cross-layer optimization. First, they provide two boundary conditions of the physical (PHY) layer and media access control (MAC) layer for a successful link establishment of mmWave neighbor discovery and to provide the optimal pairing of antenna beamwidth in different stages and scenarios using cross-layer optimization. Then, a mmWave neighbor discovery algorithm based on a spatial multi-channel is proposed, which greatly reduces the convergence time by increasing the discovery probability of nodes in the network. Finally, a random reply algorithm is proposed based on dynamic reserved time slots. By adjusting the probability of reply and the number of reserved time slots, the neighbor discovery time can be further reduced when the number of nodes is larger. Simulations show that as the network scale is 100 to 500 nodes, the convergence time is 10 times higher than that of the single channel algorithm.

Amphawan A. et al. [7] in their paper discuss the deployment of unmanned aerial vehicles (UAVs) for free space optical communications. In particular, a critical challenge to this is maintaining an acceptable signal quality between the ground base station and UAV-based free space optics relay. This is largely unattainable due to rapid UAV propeller and body movements, which result in fluctuations in the beam alignment and frequent link failures. To address this issue, linearly polarized Laguerre–Gaussian modes were leveraged for spatial mode diversity to prevent link failures over a 400 m link. Spatial mode diversity successfully improved the bit error rate by 38% to 55%. This was due to a 10% to 19% increase in the predominant mode power from spatial mode diversity. The time-varying channel matrix indicated the presence of nonlinear deterministic chaos. This opens up new possibilities for research on state space reconstruction of the channel matrix.

Pfeiffer R. et al. [8] present important foundational blocks that can be expanded into an autonomous monitoring-and-retrieval pipeline based on drone surveys and object detection using deep learning. Drone footage collected on the islands of Malta and Gozo in Sicily (Italy) and the Red Sea coast was combined with publicly available litter datasets and used to train an object detection algorithm (YOLOv5) to detect litter objects in footage recorded during drone surveys. Across all classes of litter objects, the 50–95% mean average precision (mAP50-95) was 0.252, with the performance on single well-represented classes reaching up to 0.674. We also present an approach to geolocate objects detected by the algorithm, assigning latitude and longitude coordinates to each detection. In combination with beach morphology information derived from digital elevation models (DEMs) for path finding and identifying inaccessible areas for an autonomous litter retrieval robot, this research provides important building blocks for an automated monitoring-and-retrieval pipeline.

Firdaus A.R. et al. [9] in their paper consider indoor navigation applications using the ZED2 stereo camera for the quadcopter. To use the ZED2 camera as a navigation sensor, we first transformed its coordinates into the north, east, and down (NED) system to enable the drone to understand its position and maintain stability in a particular position. The experiment was performed using a real-time application to confirm the feasibility of this approach for indoor localization. In the real-time application, we commanded the quadcopter to follow triangular and rectangular paths. The results indicated that the quadcopter was able to follow the paths and maintain its stability in specific coordinate positions.

Koukiou G. et al. [10] propose a sensor autonomous integrity monitoring (SAIM) methodology to enhance the sensors' failures in a collision avoidance system (CAS) field. The configuration of the sensors and their interaction is based on a fusion procedure that involves a total of five sensors. Accordingly, the performance of each one of the sensors is continuously checked against the combined (fused) operation of the other four. A complementary experiment with a total of four sensors, one of which had a low performance, was also conducted. The experimental results reveal a reliable approach for sensor autonomous integrity monitoring (SAIM). The method can be easily extended to a larger number of sensors.

**Funding:** This research received no external funding.

**Acknowledgments:** We would like to take this opportunity to appreciate and thank all authors for their outstanding contributions and the reviewers for their fruitful comments and feedback. Special appreciation should also be paid to Ariante Gennaro, Alberto Greco, and to the *Electronics* Editorial Office staff for their hard and precise work in maintaining a rigorous peer-review schedule and timely publication. A special thanks also to the Editorial Board of MDPI's *Electronics* journal for the opportunity to guest edit this Special Issue.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Leal, I.S.; Abeykoon, C.; Perera, Y.S. Design, simulation, analysis and optimization of PID and fuzzy based control systems for a quadcopter. *Electronics* **2021**, *10*, 2218. [CrossRef]
2. Ariante, G.; Ponte, S.; Papa, U.; Del Core, G. Estimation of airspeed, angle of attack, and sideslip for small unmanned aerial vehicles (UAVs) using a micro-pitot tube. *Electronics* **2021**, *10*, 2325. [CrossRef]
3. Zhang, R.; Cao, S.; Zhao, K.; Yu, H.; Hu, Y. A hybrid-driven optimization framework for fixed-wing uav maneuvering flight planning. *Electronics* **2021**, *10*, 2330. [CrossRef]
4. Nguyen, L.V.; Phung, M.D.; Ha, Q.P. Iterative Learning Sliding Mode Control for UAV Trajectory Tracking. *Electronics* **2021**, *10*, 2474. [CrossRef]
5. Lerro, A.; Gili, P.; Pisani, M. Verification in Relevant Environment of a Physics-Based Synthetic Sensor for Flow Angle Estimation. *Electronics* **2022**, *11*, 165. [CrossRef]
6. Song, Y.; Zeng, L.; Liu, Z.; Song, Z.; Zeng, J.; An, J. Cross-Layer Optimization Spatial Multi-Channel Directional Neighbor Discovery with Random Reply in mmWave FANET. *Electronics* **2022**, *11*, 1566. [CrossRef]
7. Amphawan, A.; Arsad, N.; Neo, T.-K.; Jasser, M.B.; Mohd Ramly, A. Post-Flood UAV-Based Free Space Optics Recovery Communications with Spatial Mode Diversity. *Electronics* **2022**, *11*, 2257. [CrossRef]
8. Pfeiffer, R.; Valentino, G.; D'Amico, S.; Piroddi, L.; Galone, L.; Calleja, S.; Farrugia, R.A.; Colica, E. Use of UAVs and Deep Learning for Beach Litter Monitoring. *Electronics* **2022**, *12*, 198. [CrossRef]
9. Firdaus, A.R.; Hutagalung, A.; Syahputra, A.; Analia, R. Indoor Localization Using Positional Tracking Feature of Stereo Camera on Quadcopter. *Electronics* **2023**, *12*, 406. [CrossRef]
10. Koukiou, G.; Anastassopoulos, V. UAV Sensors Autonomous Integrity Monitoring—SAIM. *Electronics* **2023**, *12*, 746. [CrossRef]