Research theme title:

Risk-aware control of aerial cargo drones

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Curriculum of DAUSY:

C3 AS for Monitoring and Security

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Description:

There are several applications where the use of a cargo drone can reduce costs, energy consumption, and emissions while improving safety and operational efficiency. Representative sectors that can take advantage of this include telecommunications, logistics, energy, agriculture, and forestry.

The goal is to make advances in control and trajectory planning, which are critical to operational safety, as a drone and its pilot can work cooperatively across a wide range of missions. The research will develop a comprehensive approach by leveraging the latest advances in nonlinear control, trajectory planning, and reactive collision avoidance to improve the use of cargo drones in diverse applications.

Our goals include the development of:

(a) mission models that take into account the risks presented by operational and environmental conditions;

(b) semi-automatic and automatic control algorithms to reduce drone operator burden and improve safety [4];

(c) algorithms for risk-aware trajectory planning; and

(d) algorithms for reactive collision safety control [1][2].

Scientific advances will be pursued so that they are mutually consistent and explicitly take safety into account. The methods developed will be validated through experiments performed in collaboration with FlyingBasket Srl. of Bolzano.

The challenges for developing semi- and fully autonomous drones that can operate safely in a dynamic environment and for a wide variety of missions are immense. To exploit the enormous potential of cargo drones, an approach that combines a pilot and a drone in a semi-automatic process would be more cost- and time-efficient, as well as safer. Advances could be extremely important from both a regulatory and practical standpoint for the use of drones in sectors particularly important to the local economy.

The main research question to be addressed is: "Can we improve the safety and efficiency of cargo drones through semi-automatic control?" To address this question we will explore:

1) Dynamic models - The initiative requires physical models of the drone, tether, cargo, and propulsion system. The models will be developed as part of a simulation that will include external disturbances and will be validated/recalibrated with experimental tests.

2) Robust control algorithms - The control algorithms used must be robust to large dynamic changes in the vehicle [3]. We will examine the "higher order sliding mode" control approach, which is simple to implement, requires little computing power and is robust to external disturbances.

3) Safety-critical control - Since the safety of a drone system is critical, the use of a safety controller can be of great benefit. This new technique is modular and can ensure collision-free flight, allowing the configuration of the drone to be changed without rearranging the controller.

4) Trajectory planning algorithms - Algorithms should minimize the risk of collisions between the drone/load and obstacles, as well as the possibility of the drone/load assuming unsafe situations. Planning will also take into account energy consumption to maximize operational time.

5) Experimental testing and system integration - Experiments will be performed to validate the developed algorithms and ensure that the controllers and planners are integrated. The stable mixing of signals from the human and the automatic controller is one of the most challenging aspects. Therefore, the experimental tests will proceed in three stages: a) tests of each of the components; b) tests of the automatic system; and c) tests of the semi-automatic system.

Specific Information:

Applicants must hold a master's degree, preferably in Engineering, with a good background in relevant areas of interest (i.e., optimization, nonlinear control, and robotics). Solid mathematical and coding skills are encouraged. Proficiency in both spoken and written English is required. The candidate should be highly motivated and interested in undertaking innovative and challenging research activities involving both theoretical analysis and experimental validation.

References:

[1]. Alan, A. Taylor, A. J. He, C. R. Orosz, G. and Ames, A.D. Safe controller synthesis with tunable input-to-state safe control barrier functions, IEEE Control Systems Letters, vol. 6, pp. 908–913, 2022.

[2]. Ames, A.D. Xu, X. Grizzle, J.W. and Tabuada, P. Control barrier function based quadratic programs for safety critical systems, IEEE Transactions on Automatic Control, vol. 62, no. 8, pp. 3861–3876, 2017.

[3].Munoz, F. Bonilla, M. Espinoza, E.S. Gonzalez, I. Salazar, S. and Lozano, R. (2017). Robust trajectory tracking for unmanned aircraft systems using high order sliding mode controllers-observers. In IEEE Intl Conf Unmanned Aircraft Systems (ICUAS), 346–352.
[4].von Ellenrieder, K.D. Licht, S.C. Belotti, R. and Henninger, H.C. Shared human–robot path following control of an unmanned ground vehicle. Mechatronics, 83:102750, 2022. ISSN 0957-4158. doi: https://doi.org/10.1016/j.mechatronics.2022.102750.

Type of scholarship:

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Study and research period outside the Hosting Institution:

Possible study and research period abroad:

- period length: 6 months;
- Hosting institution:
  - University of Southern California
  - Department of Aerospace and Mechanical Engineering