Master Thesis @ DTG

Single-Element Contact-Aware Aerial Robotic System

Premises - In the last decade, Thrust-Vectoring Unmanned Aerial Vehicles (TV-UAVs) are increasingly becoming an attractive research branch in both robotic and control field, thanks to the peculiar mixture of theoretical issues to be solved and technological challenges to be faced. These cutting-edge aerial platforms are usually characterized by an arbitrary number (equal or greater than four) of tilted (the orientation is fixed during flight) or tilting (the orientation is variable during flight generally thanks to the presence of servomotors) propellers, which ensures the possibility to exert the thrust force in any direction independently of the commanded torque. In this way, TV-UAVs result in fully-actuated vehicles whose maneuverability significantly outperforms that of standard quadrotors both in nominal and harsh flying conditions. For all these reasons, such aerial platforms are emerging as key technology in the industrial context, and their applications range from the classical visual sensing tasks (e.g., surveillance and monitoring activity) to the recent environment exploration and physical interaction (e.g., transportation, grasping and manipulation).

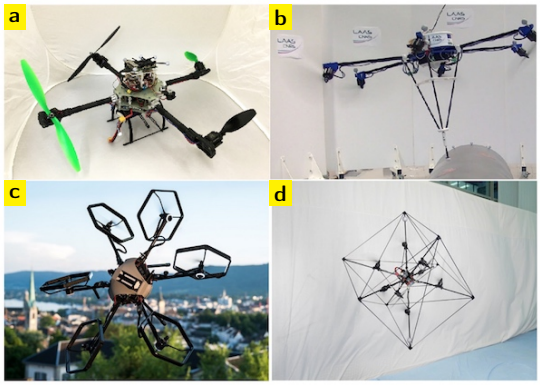

Figure 1: **Examples of TV-UAVs**
a) Tilt-arm quadrotor developed by the Aerospace Systems & Control Laboratory (ASCL) at PoliMI [Invernizzi et al. (2018)], **b)** TiltHex developed at LAAS-CNRS [Franchi et al. (2018)], **c)** Tilt-rotor UAV developed by the Voliro team at ETH Zürich [Kamel et al. (2018)], **d)** Omnidirectional Aerial Vehicle developed at ETH Zürich [Brescianini and D'Andrea (2016)].

Thesis Focus - With the intent of providing TV-UAVs with novel capabilities of physical interaction with the surrounding environment, the thesis will focus on the design of an embedded single-element contact-aware integrated system allowing the vehicle interaction with a target surface in a single contact point. In particular, the goal is to handle the presence of an end-effector consisting in a rigid tool fixed on the airframe and equipped with (optimally selected) sensors, which acts as a probing system with the purpose of inspecting the target surface, i.e., of exerting a suitable force in a specific point for a certain time period rejecting the external disturbances.

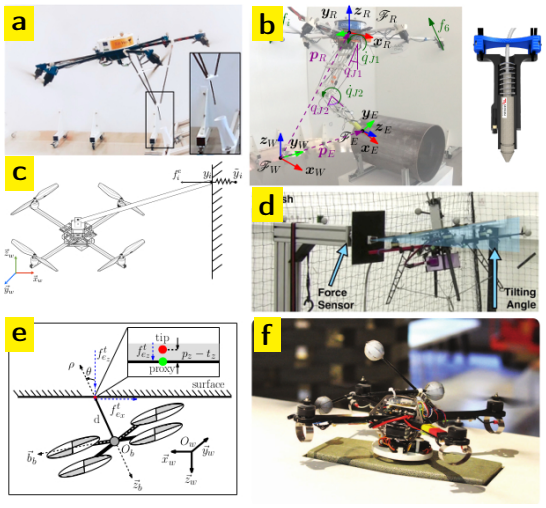

Figure 2: **Examples of TV-UAVs equipped with contact-aware systems**
a) Hexarotor equipped with a rigidly attached end-effector [Ryll et al. (2019)], **b)** Hexarotor equipped with a planar 2-DoFs lightweight arm ending with a compliant support for the sensor [Tognon et al. (2019)], **c)** Quadrotor equipped with a rigid tool [Gioioso et al. (2014a)], **d)** Quadrotor equipped with a tool tip [Gioioso et al. (2014b)], **e** Quadrotor equipped with a rigid stick [Yüksel et al. (2014)], **f)** Quadrotor equipped with a picking up module [Augugliaro et al. (2014)].

Detailed Objectives - The thesis will evolve through the fulfill of (all/some) the following steps:

- study of the existing literature related to contact-aware sensing and control;
- determination of the minimum and optimal sensors set that can be used to identify the target approaching phase and to detect the contact with the target;
- analysis of the dynamics of a TV-UAV equipped with the selected sensors set and the rigid contact-aware system;
- implementation and comparison of some state-of-the-art impact detection strategies and inspection controllers;
- physical realization of the contact-aware system and real-world tests

Expected and To-Be-Acquired Skills - From the methodological point of view, the proposed work deals with sensor signals analysis and rigid-bodies dynamics modeling and control. In addition, it involves numerical simulations in Matlab/Simulink environments and laboratory activities.

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