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Author: Mr. Luigi Colangelo
Politecnico di Torino, Italy

Mr. Carlos Perez Montenegro
Politecnico di Torino, Italy
Dr. Mauricio Alejandro Lotufo
Modelway S.r.l., Italy
Prof. Carlo Novara
Politecnico di Torino, Italy

THE BOREA PROJECT: A QUADROTOR UAV CRADLE-TO-GRAVE DESIGN FOR SPACE GNC PROTOTYPING AND TESTING

Abstract

Unmanned Aerial Vehicles (UAVs) and, more specifically, n-copters have come to prominence in the last decade due to their several applications. Also in the automatic control research community UAVs have drawn great attention, since their non-linear and under-actuated nature making them suitable for testing a wide range of control architectures and algorithms. In this paper, we summarize the most prominent theoretical aspects, simulations and experimental results of the Borea project quadrotor UAV. The Borea project aims at testing space guidance, navigation, and control (GNC) algorithms leveraging a simplified, rapidly prototypable, low-cost, and easy-to-test quadrotor platform. More precisely, one of the main project objectives will consist in testing Moon and Mars planetary landing algorithms, thanks to the similitude, in the command authority and the landing approach, between n-copters and spacecraft; during the propulsive landing phase. Indeed, both n-copters and spacecraft are able to provide a thrust vector characterized by constant direction and adjustable magnitude. This similitude approach makes it possible to anticipate issues and avoid failures such as those that occurred in the Schiaparelli Mars Lander. To this aim, the complete control unit design, and the UAV plant electro-mechanical prototyping were addressed; so far. Specifically, the control unit was designed within the framework of the Embedded Model Control (EMC) methodology. The EMC design, based on an internal model, also includes the uncertainties as disturbances to be estimated and actively rejected. As a result, the Borea UAV has been endowed with a control system leveraging a wide range of automatic control concepts, ranging from modelling, identification, and linear and non-linear control laws, to deal with its position, velocity, and attitude regulation. To sum up, all these results were achieved by means of a properly structured cradle-to-grave design process which, starting from the simultaneous plant modelling and prototyping, ended up with a complete flight tests campaign. Most notably, the testing process involved intensive numerical simulations as well as multi-stage hardware/plant tests and models validations. From the control perspective, the several developed controllers were tuned and tested, via proper simulations and on-purpose flight tests, aiming at validate, from time to time, specific functionalities and control performances. Finally, some results coming from high-fidelity simulations, the hardware and model testing, and in-flight operations will be provided to underline the most relevant aspects of the Borea plant and control unit performance.