ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

DET - Advanced GNC Algorithms for Novel Near-Earth and Exploration Missions

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Dipartimento DET
Supervisor	NOVARA CARLO - carlo.novara@polito.it
Contact	STESINA FABRIZIO - fabrizio.stesina@polito.it
Context of the research activity	The research involves the development of innovative systems for orbital guidance, navigation control, and attitude determination and control of spacecraft in distributed configuration, such as formation/constellation flight for Earth Observation and proximity operations. Relevant topics are the definition of new visual navigation algorithms, effective and robust state estimators, new control algorithms based on advanced techniques. The most promising solutions will be implemented in hardware for real-time applications and a verification through test benches is also planned.
	The research area is “Enabling Technologies for Novel Near-Earth and Exploration Missions”, spoke 1 of PE 15 of the PNRR. Enabling technologies are of primary importance for future space missions. Among these technologies, the ability to control the position and attitude of a space system engaged in increasingly complex missions is critical. Guidance, navigation and control systems and attitude determination and control systems are therefore fundamental and require continuous technological innovation and continuous improvement of performance based on faster and more reliable instruments. The objectives of this research are the development of modern and advanced solutions for guidance, navigation and control in cooperating spacecraft missions such as formation flight (both swarm and distributed architectures) and proximity operations (rendezvous and docking/berthing missions), the implementation of the solutions studied on embedded systems and prototypes, and the verification through analysis and tests with the help of test benches of the solutions found. The main research topics are: 1) definition of the relative pose estimation between two objects in orbit by exploiting both images and measurements of

Objectives	radio frequency sensors; 2) development of effective and robust state estimators (i.e., capable of providing real-time solutions while maintaining high reliability of the results provided even in the presence of noise and uncertainties due to the system and the space environment); 3) robust control systems capable of ensuring the correct positioning and attitude of each spacecraft both in the case of nominal operation and in case of failure of the system elements; 4) efficient networked control systems, able to manage large formations of satellites. Optical navigation involves the use of both real and synthetic images on which image processing techniques can be applied, from which the main features can be obtained, also through the use of artificial intelligence (e.g. neural networks) and advanced optimization algorithms. Modern solutions for segmentation, feature detection, centroid definition and marker recognition must be found out. Navigation based on radio frequency instruments involves the development of innovative techniques for using GNSS signals to define the relative position between two spacecraft. The development of state estimators involves the use of outputs from optical navigation and radio frequency navigation to find effective solutions in terms of low computational cost without losing quality in the estimation. The solutions shall consider the presence in orbit of sources of disturbance and intermittent or permanent malfunctions of the measurement systems. The control systems will be based on optimal, predictive and robust techniques, and also on solutions based on artificial intelligence. The possible solutions will have to be robust to work properly in a hostile environment such as space and will have to take into account the performance and architectures of the available technology. Simulation of the solutions found will be carried out using high-fidelity models that include the details of dynamics and kinematics, disturbances, sensors and actuators, in order to realistically reproduce the context in which the systems will operate. The most promising solutions will be implemented on prototypes of an on-board system. Therefore, the algorithms will have to be cross-compiled to be hosted on dedicated hardware, and including sensors and actuators, suitably stimulated or emulated. The verification scenario includes simulations in the loop campaigns. The research activity plan is organised in three years: in the first year of activity there will be an in-depth research and analysis of the state of the art of the main research topics and the definition of the first solutions for navigation and control. In the second year, the detailed definition and development of all possible solutions is planned, their evaluation through analysis and the selection of the most promising ones in order to implement them on prototypes. In the third year, the verification on test benches and the final documentation of the research are foreseen. Over the course of the three years, dissemination of the results in congresses and in specialized journals of the sector is planned.

Skills and competencies for the development of the activity	Automatic control; attitude kinematics and dynamics of satellites; orbital dynamics; GNC design for space vehicles; AI-based navigation; optimization methods; simulation of complex systems; Matlab/Simulink.