POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 37th cycle

THEMATIC Research Field: ROBUST GNC TECHNIQUES FOR FREE-FLYING SPACE MANIPULATORS OPERATIONS

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Satellites travel far above the Earth and provide crucial (but often overlooked) services to people worldwide. Interruption of those services may jeopardize their vital contribution to the economic and social development on Earth. With the expansion of the in-orbit objects population, the risk of potential service interruption increases due to the limited capability of replacing or reconfiguring existing satellites after a failure. This problem has been faced in the past by adopting multiple active satellites to serve the same purpose, thus guaranteeing a hot redundant approach and the consequent mitigation of service interruption risks due to failures or unavailability (i.e. during collision avoidance maneuvers) of a subset of the satellites. However, as the number of in-orbit objects increases, this approach tends to be unfeasible or inefficient, and two possible actions can be taken: removal of non-active objects (to reduce the population size) and extension of the operational life of active ones (in orbit servicing). Both actions will require the use of proper capturing devices, among which the use of free-flying space manipulators is being evaluated and proposed. The use of a space manipulator mounted on an orbiting platform will pose relevant challenges to the guidance, navigation, and control of the platform, especially when the large uncertainties associated with uncooperative objects are considered. Based on the above considerations, the objective of the research activity is twofold. On one hand, it is to develop

	innovative, accurate, and numerically efficient methods to solve the navigation problem, allowing the identification of the relative pose of unknown and uncooperative targets. The validity of the methods shall be general enough to be applied to any kind of object, exploiting the capabilities of a free-flying space manipulator. On the other hand, the purpose is to develop innovative robust guidance strategies exploiting both the output of the navigation block and the inherent combined dynamics and actuation provided by a free-flying space manipulator.
Methods and techniques that will be developed and used to carry out the research	The activity will start with a review of the current approaches to the solution of both the navigation and guidance/control problem for free-floating and free-flying space manipulators. In parallel, a review of the technological solution currently adopted for sensors and actuators will be conducted, focusing also on the dynamics modeling framework most suitable for the guidance and navigation problems. The most promising modeling framework currently available (dual-quaternions and spatial vector notation) will be evaluated. The activity will proceed with the study of the navigation problem, in which optical sensors will be exploited to derive the relative pose measurements, eventually considering cameras mounted both on the manipulator end-effector and on the spacecraft body. In the case of an uncollaborative and unknown target, the activity will assume the availability of data coming from a previously performed inspection phase, therefore, potentially exploiting higher-level information deriving from that phase. The activity will then move to study the guidance/control problem, in which the full combined dynamics (spacecraft position and attitude together with space manipulator) will be exploited to design robust trajectories for the end-effector. This phase will take advantage of the measurements coming from the identified navigation solution and the inspection phase. In the solution of the guidance problem, the introduction of time-varying path constraints will be necessary to tackle the collision avoidance problem with appendages on the target. Moreover, the inherent uncertainty on the knowledge of the target properties (eventually identified

	as part of the navigation problem), will require proper modeling of the uncertain parameters and the identification of a robust guidance strategy. The research activities could also benefit from artificial intelligence algorithms. In the case of the navigation problem, a supervised machine learning framework can be used in the navigational filter design, while a reinforcement learning framework can be applied to the guidance problem to improve its robustness features.
Educational objectives	The main educational objectives are: - the acquisition of a solid background on cutting-edge methodologies for GNC of free-flying space manipulators - the development of skills in advanced numerical methods, software engineering, and data-analytics techniques - the development of key capabilities in the fervent area of GNC of free-flying space manipulators for proximity operations (inspection, active debris removal, on-orbit service, etc.)
Job opportunities	The research will develop in parallel to the establishment of: 1. ESA¿s Clean Space program 2. ESA¿s ARTES program Both programs support the development of innovative technologies aimed at the solution of the in-orbit-servicing and active-debris-removal problems. To this purpose, both programs are fostering industrial and academic excellence in the field, which will need the long-term support of experienced professionals.
Composition of the research group	0 Full Professors 2 Associated Professors 0 Assistant Professors 0 PhD Students
Name of the research directors	Prof. Mauro Massari and prof. Pierluigi Di Lizia

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	566.36 €
By number of months	0

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The Ph.D. candidate will receive a desk, a personal computer. Apart from the compulsory ones, the Ph.D. candidate will have the opportunity to follow additional courses, receive economic support to attend summer schools, and participate in conferences. There will be the possibility of paid teaching assistantship.