POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

PNRR 117 Research Field: USING STAR TRACKER FOR AUTONOMOUS NAVIGATION AND IN-SPACE OBJECTS DETECTION

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 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	Star trackers are commonly used to determine the inertial attitude of a spacecraft. They do so by detecting, tracking, and matching observed stars with star catalogues stored onboard. The peculiarity of such an imaging sensor is that it is composed of different optical elements mounted within the same optical head. These serve two purposes: to limit the amount of stray light entering the sensor and, crucially, to intentionally defocus the light from the incoming stars. Similarly, to perform relative navigation with other celestial bodies such as moons, planets, asteroids, and comets, another imaging sensor commonly referred to as a navigation camera, is needed to resolve the body in the image. On a deep-space spacecraft, this leads to the presence of at least two imaging sensors, each responding to different tasks. The first objective of this PhD project is to assess the feasibility of image processing algorithms for spacecraft navigation using star tracker images, which by design are not developed for such tasks. The second objective is to use the star trackers to detect artificial objects passing in their field of view, so providing valuable and cost-effective information to space situational awareness. The underlying idea is to use the same hardware to accomplish side tasks as a by-product of mere attitude determination. This would reduce the number of hardware needed on the spacecraft, with benefits in terms of costs, mass, and volume available onboard.

Methods and techniques that will be developed and used to carry out the research	The PhD project foresees three tasks. First, an image processing algorithm will be developed to detect unresolved celestial bodies and artificial objects in the star tracker field of view by using synthetic images. Second, a navigation filter will be developed to find a navigation solution or to correlate the detected object. The algorithm is intended to run onboard, and as such it has to be developed by considering spacecraft hardware limitations. Eventually, both the image processing algorithm and the navigation filter will be deployed on representative hardware. Third, a fully integrated simulation with both a star tracker and an onboard computer in the loop will be carried out. The validation campaign is aimed to prove the applicability of the image processing and navigation algorithm on a real star tracker and of an onboard processor. This will be done by performing hardware-in-the-loop simulations run in an existing hardware test bench. The selected scenarios will first be simulated synthetically. This is of strong importance as it provides repeatability of the simulations and a ground truth available to be used for comparison. Initially, a virtual simulated world is defined where the celestial bodies and the camera are positioned and characterized. From this simulated virtual 3D world, a dedicated renderer will generate images to be displayed on the screen.
Educational objectives	The objective of this PhD is to develop skills in space system modelling and simulation as well as in autonomous guidance, navigation, and control. The candidate will gain relevant expertise in near-Earth and deep-space missions. Through this project, the candidates will develop skills in mathematical modelling, numerical analysis, computer programming (Matlab, Python, C++, or similar), and image processing. Moreover, the candidate will develop skills in both computer and processor/hardware-in-the-loop simulations. Soft skills in disseminating the research, writing reports, performing outreach, and preparing industrial progress meetings will be also achieved through the PhD project. These educational objectives will be also acquired through a six-month secondment at Leonardo company, a world-leading star tracker manufacturer. In

	addition, the PhD student is supposed to spend six months at the European Space Agency (TBC). The timeframe and location of the secondment as well as the period abroad will be defined during the PhD career development plan, to be developed within the first semester after the kick-off of the activity.
Job opportunities	The current research prepares the PhD candidate for both academic and industrial careers. Knowledge of model-based system engineering, modelling and simulation of space systems, as well as autonomous guidance, navigation, and control are fundamental skills for careers in space-related companies and universities.
Composition of the research group	1 Full Professors 0 Associated Professors 3 Assistant Professors 18 PhD Students
Name of the research directors	Prof. Francesco Topputo

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	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Leonardo S.p.A.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	ESA (NL)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The candidate will be hosted at the DART Lab (Deep-space Astrodynamics Research &Technology Laboratory) at the Department of Aerospace Science and Technology, Politecnico di Milano. During the PhD program, the candidate will have access to the facilities of the DART Lab to carry out experimental activities. The candidate will also have the opportunity to attend some PhD classes on both soft and hard skills. The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.