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A LABORATORY FACILITY TO TEST VISION-AIDED DOCKING STRATEGIES WITH NO-COOPERATIVE TARGETS

Abstract

Nowadays autonomous proximity and docking maneuvering in space represents one of the key techniques to make several space missions feasible: in orbit re-fuelling, debris mitigation, large orbiting structures building, planetary specimen collection an return to Earth, humans space transportation, in space system reconfigurations, formation flying control are just some of the applicative examples which would benefit of any enhancement in the underlined technological field.

Apart from the International Space Station related experience, which still sees the human operator in the control loop, actual autonomous docking maneuvering applications in space lack, although the correspondent scientific research and on ground testing is quite active in many of the involved technical areas. Among the fundamental aspects such a maneuvering has to deal with, precise state reconstruction and fine control are two challenging topics, strongly dependent on the selected docking mechanism.

At Politecnico di Milano, Dipartimento di Ingegneria Aerospaziale a dedicated facility to test proximity and docking control algorithms is being implemented.

The paper highlights both the testbed design and realization and the closed loop control implemented to simulate autonomous proximity maneuvering. The project includes two vehicles floating on air pads on a frictionless glass surface. Each vehicle is equipped with a camera, an IMU platform and four fans, as actuators. The vehicle brain is represented by a PC104+ unit. The target vehicle is provided with a set of leds to further guide the chaser to the correct docking.

The vehicles are completely autonomous: a compressed air tank each to feed the pads, Ion-Lithium batteries for power supply and a wireless board for TMTC. The overall mass is about 15 kg while a 30 Wh energy supply allows an experimental campaign of 20 min. A quite simple docking mechanism has been implemented made of a passive male-plate on the target, and an active female-clamp-actuated by a linear motor on the chaser. To limit the accelerometer and gyroscope drift and bias errors a discrete Kalman filter has been implemented in the observer module, part of software control chain. The final approaching phases are supported by the vision sensor too and relative position and attitude are gained by means of triangulation.

A PD, LQR and non-linear Lyapunov controllers have been separately implemented to perform a critical trade-off before selection according to speed and fluctuations criteria, during the final docking phase. Both software simulations and preliminary experimental results are presented and discussed in the paper.