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Author: Mr. Massimo Lucia
Leonardo Spa, Italy

Mr. Andrea Rusconi
Leonardo Spa, Italy
Dr. Guido Sangiovanni
Leonardo Spa, Italy
Mr. Luca Foresti
Leonardo Spa, Italy
Mr. Enrico Cunietti
Leonardo Spa, Italy
Ms. Margherita Marchi
Leonardo Spa, Italy
Mr. Leonardo Bertelli
Leonardo Spa, Italy
Mr. Joaquín Estremera Rodrigo
GMV Aerospace & Defence SAU, Spain
Dr. Isacco Pretto
OHB Italia SpA, Italy
Mr. Mario Esposito
OHB Italia SpA, Italy
Mr. Dominik Frey
maxon motor, Germany
Mrs. Florbela Costa
maxon motor, Switzerland
Mr. Phillips Robin
maxon motor, Switzerland
Prof. Nikolaos Tsagarakis
Italian Institute of Technology (IIT), Italy
Mr. Davide Antonucci
Italian Institute of Technology (IIT), Italy
Dr. Stefano Cordasco
Italian Institute of Technology (IIT), Italy
Mr. Alessio Margan
Italian Institute of Technology (IIT), Italy
Dr. Davide Nicolis
European Space Agency (ESA), The Netherlands
Mr. Philippe Schoonejans
European Space Agency (ESA), The Netherlands
Mr. Kjetil Wormnes
European Space Agency (ESA), The Netherlands

Abstract

Within the Mars Sample Return (MSR) mission, a breadboard (BB) model of the Sample Transfer Arm (STA) to be mounted on the JPL Sample Retrieval Lander (SRL) has been studied and developed. The STA will be the robotic arm in charge of transferring the Mars samples, cached and encapsulated by NASA/JPL Perseverance, from two rovers, Perseverance itself and ESA Sample Fetch Rover (SFR), to the Orbiting Sample container (OS) into the SRL. The OS will be then launched from Mars surface and collected in orbit by ESA Earth Return Orbiter (ERO) to start its journey back to Earth.
A test campaign was carried out on the STA BB simulating Mars surface mission including the extraction of the sample tubes from a storage mockup representative of SFR's unit, the insertion of the samples into the OS and the OS closeout with a OS lid mockup. The entire mission is autonomously carried out by the robotic arm with minimal intervention (physical or with SW commands) from the operators.
The BB STA architecture consists of: a base to install the arm at the sustain structure, a 7 degrees of freedom (DoF) arm composed by 7 joints and two link structures, a single DoF End Effector (EE), a Force/Torque Sensor (FTS) and a vision camera for a total length of more than 2m. A torque sensor is additionally embedded in each joint. The servo control of the STA is provided by 8 Servo Control Units (SCUs) installed locally at each joint and at the End Effector. Each joint has a travel capability of 340 degrees. The total mass of the system is less than 30kg providing a payload capacity of 3 kg.
The High level software (HSW) with its Motion Control Library have been also developed, implementing the trajectory planning and execution, the vision (camera) based control, the FTS/Joint torque sensors signal acquisition and performing the force/impedance control as well as the inverse kinematics computation.
The study and the test campaign were done to demonstrate the STA BB capability to retrieve cached samples in different scenarios:

- from the Perseverance rover, by positioning a tube collector tray beneath the rover belly. The sample tubes are released by the rover into the tray and the STA collects and manipulates them, performing the needed sample tube interface change re-grasps, before insertion into the OS;
- from SFR, by extracting the sample tubes directly from the tube storage and inserting them into the OS;
- from the surface, by handling the sample tubes with a "body grip" and performing the grasp change before final insertion into the OS.

The STA BB moved to the rovers working area, localized each sample tube with the aid of the camera mounted on the tip of the arm, then passed this information to the control algorithm of the arm in order to determine the Cartesian motion that the arm shall perform to achieve the target. With this information, the gripper has been conceived so that no additional sensors are necessary to grasp the cached sample.
The End Effector has been designed to perform a "form grasping" through a passive grip concept. The jaws profile is shaped to fit into the sample tube "end grip" grooves. The combination of the angular position of a cam into the mechanical chain and the action of springs drove the opening and closure operation of the jaws. Once the desired closure position has been reached, two mechanical latches (hooks), shaped at cam's sides, engaged dedicated pins with the aim to secure the gripper after the target capture.
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