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DESIGNING AND TESTING A ROBOTIC AVATAR FOR SPACE-TO-GROUND TELEOPERATION: THE DEVELOPERS' INSIGHTS

Abstract

In late 2019 astronaut Luca Parmitano remotely controlled a rover equipped with a robotic manipulator, performing geology tasks on a moon-analog site from the ISS. 7 months later, in July 2020, he controls the same rover in a more realistic moon-analog environment: a field of volcanic rock and regolith on mount Etna, Italy. These experiments constitute the ANALOG-1 campaign in the frame of ESA's METERON project.

As payload developers, we are interested in creating an interface for astronauts to intuitively operate robotic systems on a planetary or lunar surface: how can we maximise efficiency and sense of immersion/transparency? At the same time, how can we minimise operator fatigue, and physical and mental effort?

In this paper we show how we created a telerobotic system featuring an intuitive graphical and haptic user interface. This included a force feedback device and custom joystick, controlling a mobile robotic platform. The robotic platform consisted of an all-terrain chassis and two 7-degree-of-freedom (7-DOF) robotic arms with torque sensing. One arm was mounted on the front of the rover and used for manipulation; the other was mounted on top and used to reposition a camera. With this system, the astronaut was fully in control of the robot to collect rock samples. The only external input was from a ground team of scientists over voice-loop and text-messenger, concerning the choice of geological samples.

Full 6-DOF force feedback for the manipulation arm was provided via a Sigma.7 haptic input device, and stability was ensured despite a round-trip time delay of over 800ms. This meant that the astronaut could feel (for the first time from space) not only full-DOF contact with the planet surface from orbit, but also the weight of the rocks they grasped. System status feedback was visually and intuitively presented on the user interface, which was run on a laptop on board the ISS. Views from the camera on top of the rover and from another camera mounted on the manipulation arm were available to the astronaut at all times.

During development we continuously integrated requirements from various stakeholders and feedback from astronauts and astronaut trainers to improve the user interface. The analog tests delivered valuable insights about how to design a telepresence system to control robots on a planet's surface from orbit. We expect these insights to be useful for future development of teleoperated planetary robotics as well as terrestrial applications in similar scenarios.