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SEMANTIC STATE ESTIMATION FOR EFFICIENT ASTRONAUT-ROBOT COLLABORATION USING SCALABLE AUTONOMY IN THE SURFACE AVATAR EXPERIMENTS

Abstract

Future exploratory space missions to distant celestial bodies will depend on increasingly capable robotic systems. For a crewed mission to Mars we foresee robots to setup, prepare, and maintain the environment for the first astronauts to land. Furthermore, the construction of a lunar base will be predominantly, if not completely, performed by robots. While communication time delay hinders direct teleoperation possibility over long distances, recent advances in control in these conditions have paved the way for its use in cislunar space. For distant planets, an orbiting spacecraft would enable the crew to teleoperate a robotic team with an array of different modalities including direct teleoperation, haptic telepresence, and supervised autonomy. As direct teleoperation exerts high cognitive load on the operator, most robotic tasks will, however, be carried out in supervised autonomy by the robots rather than through direct teleoperation. Nevertheless, direct teleoperation can be useful in a variety of use cases, including the recovery of the robot from failures or when encountering unforeseen situations. Being able to seamlessly switch between direct teleoperation and autonomous operation brings forward efficient operation in this context. This multi-modal teleoperation approach is currently being studied in the DLR/ESA International Space Station

(ISS)-to-Ground telerobotic experiment mission, Surface Avatar. In our first ISS session, we demonstrated the combination of direct teleoperation modalities and supervised autonomy to recover a robot from a simulated failure. One of the challenges in combining these modalities lies in tracking the change of the semantic state of the environment during teleoperation as the robot requires an adequate semantic world state to be able to continue autonomously afterwards. Although this update can happen manually, it is laborious and requires expertise in the domain definition language used for planning the autonomous task sequences. Furthermore, an astronaut operating a fleet of robots is not expected to know details of the planning algorithms deployed on each robot. To address these concerns, we propose a framework for updating the semantic world state autonomously when transitioning from direct teleoperation to autonomous operation. This paper describes the framework and its implementation to automatically update the semantic world state based on inputs from vision, communication with smart assets, and joint-level sensor readings of the robot. The framework enables seamless switching between direct teleoperation and autonomous operation. We demonstrate and validate our framework on the humanoid robot Rollin' Justin, including the first Surface Avatar ISS-to-Ground prime session, currently scheduled for July 2023.