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TOWARD ROBUST TASK EXECUTION THROUGH TELEROBOTIC FAILURE RECOVERY IN SPACE OPERATIONS

Abstract

Robots will play a key role in future missions to distant celestial bodies. Their fields of contribution will expand from planetary exploration to construction and maintenance on the surface prior to the astronauts' landing. Operating robots over such long distances becomes a key challenge due to limited bandwidth and communication delay. One way to deal with this problem is to tediously define the task sequence of the robots before launch, with only minimal interaction possibilities during the mission. However, the uncertainty of unknown environments during a space mission limits the complexity of predefined tasks. An approach that offers improved interactions during the mission is to command the robots from a spacecraft orbiting the celestial body on which the robots are located. This setup reduces the time delay between operator and robot allowing for more detailed robot commands up the way to direct teleoperation. In the International Space Station (ISS)-to-Earth telerobotic experiment, Surface Avatar, a team of heterogeneous robots located in Munich, Germany, is commanded from orbit. Surface Avatar examines the use of Scalable Autonomy, which enables robotic command using different levels of abstraction, from immersive direct teleoperation to supervised autonomy. By issuing commands in supervised autonomy, a task is delegated to the robot for autonomous execution. This reduces both communication resources, and crew cognitive load. However, these tasks run the risk of execution failures, particularly in uncertain environments. While the robot may be able to recover from some failures, the robotic engineers are unable to anticipate every possible failure due to the sheer number of possible anomalies, especially in unknown space environments. In order to recover from failed actions, we propose a telerobotic failure recovery approach. In our approach, failure detection by the robot is integrated with proactive support request to the astronaut or ground control. This reduces the need for constant supervision of the robot. While robotic and mission experts on ground can correct false assumptions in the robot's environmental model, astronauts can take over control of the robot by means of direct teleoperation. Thus, the team can recover from anomalies and bring the robot back into a nominal state from which it can continue autonomously. We validate this concept in an ISS-to-Earth session with an astronaut on orbit commanding a dexterous mobile robot in our simulated Martian surface environment. The astronaut-robot team demonstrates successful recovery from a simulated failure during autonomous task execution.