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TOWARDS AUTONOMOUS OPERATIONS OF THE ROBONAUT 2 HUMANOID ROBOTIC TESTBED

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The Robonaut project has been conducting research in robotics technology on board the International Space Station (ISS) since 2012. Recently, the original upper body humanoid robot was upgraded by the addition of two climbing manipulators ("legs"), more capable processors, and new sensors, as shown in Figure 1. While Robonaut 2 (R2) has been working through checkout exercises on orbit following the upgrade, technology development on the ground has continued to advance. Through the Active Reduced Gravity Offload System (ARGOS), the Robonaut team has been able to develop technologies that will enable full operation of the robotic testbed on orbit using similar robots located at the Johnson Space Center. Once these technologies have been vetted in this way, they will be implemented and tested on the R2 unit on board the ISS. The goal of this work is to create a fully-featured robotics research platform on board the ISS to increase the technology readiness level of technologies that will aid in future exploration missions.

Technology development has thus far followed two main paths, autonomous climbing and efficient tool manipulation. Central to both technologies has been the incorporation of a human robotic interaction paradigm that involves the visualization of sensory and pre-planned command data with models of the robot and its environment . Figure 2 shows screenshots of these interactive tools, built

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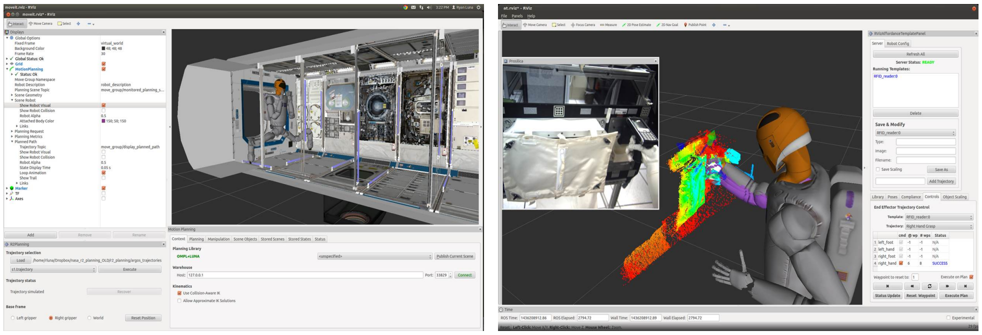
Figure 1: Robonaut 2



(a) (b)

Figure 2: Advanced User Interfaces: a) Climbing GUI, b) Manipulation GUI

in rviz*, that are used to develop and implement these technologies on R2.

Robonaut 2 is designed to move along the handrails and seat track around the US lab inside the ISS. This is difficult for many reasons, namely the environment is cluttered and constrained, the robot has many degrees of freedom (DOF) it can utilize for climbing, and remote commanding for precision tasks such as grasping handrails is time-consuming and difficult. Because of this, it is important to develop the technologies needed to allow the robot to reach operator-specified positions as autonomously as possible. The most important progress in this area has been the work towards efficient path planning for high DOF, highly constrained systems. Other advances include machine vision algorithms for localizing and automatically docking with handrails, the ability of the operator to place obstacles in the robot's virtual environment, autonomous obstacle avoidance techniques, and constraint management.

The dexterity of Robonaut 2 lends itself to effective manipulation of tools, but constructing and sending low level commands to the robot from the ground has proven to be inefficient. Building on an existing Affordance Template framework, the team has added several key functionalities to further reduce the operator workload for manipulating tools. In this framework, a model of the tool is developed along with a template of the manipulations (grasp points, approach angles, etc.) that the object affords. A grasp library was integrated into the tool to allow the operator to pre-select the appropriate grasp (developed from the Cutkowski taxonomy) into the affordance template. Finally, a stereo placement algorithm is created for each tool to allow it to snap into place in the robot's reference frame to reduce operator time spent adjusting the placement of the tool models. Using these technologies has allowed increased operator efficacy when commanding tool manipulations on the remote robot, as tested in ARGOS.

These developments were integrated into a simulated RFID-tagged tool finding demonstration in an ISS mockup in ARGOS. R2 first autonomously unstows from its stowage rack, and then climbs across three racks using the novel path planning algorithm to a worksite. The worksite consists of a RFID reader and a compartment covered by a blanket attached with quarter turn fasteners. R2 is commanded to grasp the RFID reader, activate it, and scan the blanket-covered compartment. The robot checks to see if the missing tool is present under the panel, and if so, manipulates the quarter turn fasteners using previously designed affordance templates, pulls back the blanket, and acquires the tool.

*`http://wiki.ros.org/rviz`