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KNOWLEDGE DRIVEN USER INTERFACE DESIGN FOR SCALABLE AUTONOMY COMMAND OF A ROBOTIC TEAM

Abstract

In the future, planetary expeditions involving human crew will require the assistance of robots to support the setup and inspection of vital assets, like return vehicles, before and after the crew's arrival. To effectively manage the diverse tasks, a heterogeneous robot team will be employed, commanded with various levels of autonomy using a flexible and user-friendly Robot Command Terminal (RCT) onboard the crewed spacecraft.

Our approach for robot commanding is based on an object-centered prior knowledge management system, which contains the information for detecting, reasoning on, and interacting with objects in the robot's surrounding. Action Templates (ATs) enable the hybrid planning of tasks, using both symbolic and geometric reasoning to determine the feasibility and appropriate parameterization of actions. Treating the robot itself as an object allows to integrate traditional robot-centric skill sets by defining corresponding ATs. The symbolic reasoning on all available AT's of the objects in the environment of the robot is used to create a list of currently feasible high-level robot actions that is used for robot commanding. A mission control instance allows mission experts to customize the available commands for specific users, robots, or scenarios.

The operator uses the RCT to command the robot team based on the object-based commands generated by each robot. A Multi-Robot World State Representation (MRWSR) is used to instantiate the actual objects with their properties and serves as a robot-agnostic interface to the planetary assets. By selecting a target robot and an object of interest in the RCT, the available commands displayed in the user interface are filtered in order to reduce the mental effort for the operator. Robot-specific teleoperation skills can be accessed via their respective ATs and are mapped dynamically to the available input devices. AT-specific parameters provided by the robot for each input device allow for robot-agnostic usage, and the use of different control modes based on the current communication characteristics.

In two preliminary sessions of the Surface Avatar space telerobotics experiment suite, the feasibility of the knowledge driven robot commanding concept has been demonstrated with astronauts on board the ISS and a robot on Earth. The RCT has been used to directly command the target robot using velocity, model-mediated, or domain-based passivity control, as well as task-level commands. The scaling of the autonomy level of the robotic avatar allowed the astronaut to efficiently execute a variety of demonstration scenarios that exceeded the autonomous capabilities of the robot alone.