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TOWARDS REDUCING ASTRONAUT WORKLOAD WITH SCALABLE AUTONOMY IN PLANETARY ROBOTICS TELEOPERATION

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ABSTRACT

Operating robots on a planetary or lunar surface brings several challenges. One such is the intuitive operation of multiple robots without inducing operator fatigue. For this, it is desirable to scale up the autonomy of the robots, so that the operator can give higher-level commands. The challenge is that many technologies for robot autonomy rely on conditions that are not present in space situations, such as diffuse lighting or structured environments. The ANALOG-1 mission aimed to test teleoperation for lunar geology. The first leg, ANALOG-1 ISS, was performed with a realistic space segment but a less realistic ground segment (a disused aircraft hangar). The second leg, as part of DLR's ARCHES mission on Mt. Etna, provides a more realistic moon analog. This will be the testing ground for the presented features.

Key words: teleoperation, robotics, supervised autonomy, scalable autonomy, augmented reality.

1. INTRODUCTION

In more structured environments, Supervised Autonomy can be used to relieve the operator workload and allow faster commanding of complex tasks [LRL+18, SLK+18]. However, in the unstructured, often poorly lit environment of planetary surfaces, autonomy can be a challenge. Common solutions for automation in robotics, which require known or structured environments with good conditions for computer vision, may not work, or need to be adapted. With *Scalable Autonomy*, the operator is able to scale up or down the level of autonomy, from direct teleoperation to Supervised Autonomy, according to their needs.

In this paper, we investigate what is feasible, what is desired based on experience from previous teleoperation missions, and our progress towards Supervised Autonomy on planetary rovers.

1.1. Removing time and concentration intensive processes

In the Analog-1 experiment [WCK+21, KFG+20], an astronaut teleoperated a mobile robotic platform from the ISS. In this experiment we identified time- and concentration-intensive processes during rover operation. One was the operation of the robot manipulators. The operator used the manipulators to look around, pick up rock samples, and deposit them in a sample container. While looking around cannot (and need not) be automated, picking and deposition of rock samples can. The deposition of an already-picked sample can be

It is also highly likely that low-level teleoperation with force feedback will still be an indispensable function of the robot, for unexpected/unforeseen situations, and situations where autonomy fails. Therefore this autonomy should complement, but not replace, the possibility for low-level teleoperation.

1.2. Augmented Reality

We also identified that the operator had trouble visualising the movement/position of the rover or its manipulator–situational awareness. We plan to solve this with more useful telemetry data and augmented reality.

2. LOCALISATION AND NAVIGATION

Lidar is a robust sensing depth-sensing modality that has been used in autonomous vehicles and is not dependant on the lighting conditions. With Lidar a 3-D map of the environment is built, where the terrain and obstacles can be classified according to their navigability. This feeds in to a trajectory planner which creates a navigable path from user-specified waypoints.

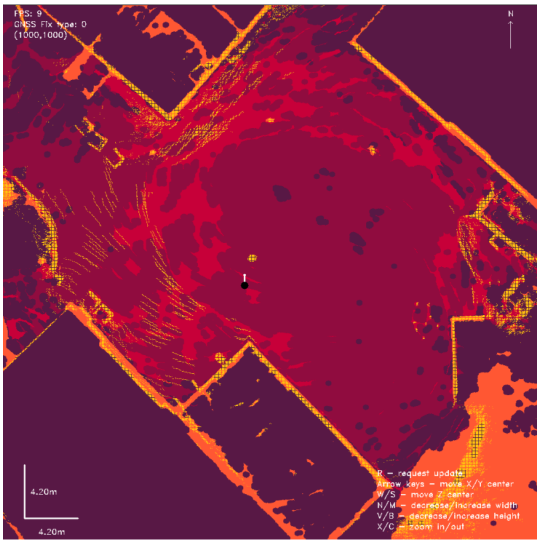

Figure 1. Map with classifications: Dark purple is undiscovered, dark red is ground, light red is clearable elevated terrain. Orange is a clearable obstacle and yellow is a blocking obstacle.

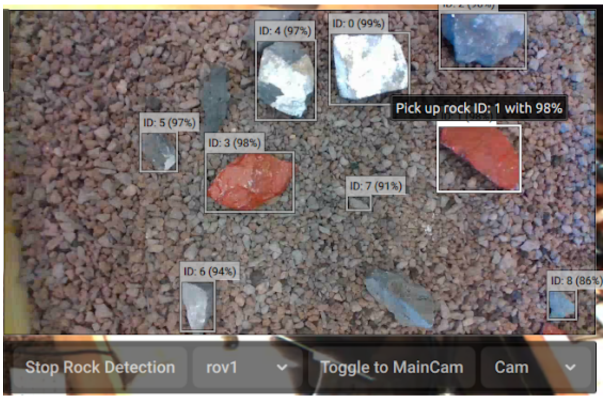

Figure 2. Cutout of the rover operator GUI, showing the detected rocks and their percentage match. An automated rock-pick can by commanded by clicking on the rock.

3. AUTOMATED SAMPLE COLLECTION

Identifying pickable rocks from camera images is a challenge. We trained Region-Based Convolutional Neural Networks (RCNNs) on images from the NASA PDS Image Atlas. Using an RGB-D Camera mounted on the robot manipulator end effector, we were able to identify rocks in front of the rover and determine their position. The operator can then choose to pick them automatically. Compliance in the robot is necessary to allow safe interaction with the ground by limiting forces. Inherently soft manipulators are not made of materials that can be used in space. However, a manipulator with torque sensors, such as TINA [MBB+21], can be operated in Cartesian Impedance Control and therefore interact safely with rocky environments.

4. ANALOG EXPERIMENT

The presented scalable autonomy features are planned to be tested during the ARCHES campaign on Mount Etna. Here we can evaluate their usefulness to an operator in a realistic scenario and identify more features that can aid in reducing astronaut workload.

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