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A SYMBIOTIC HUMAN AND MULTI-ROBOT PLANETARY EXPLORATION SYSTEM

Abstract

The availability of next generation heavy launchers—such as NASA's SLS and SpaceX's Falcon Heavy—will enable new planetary exploration missions. Most space agencies are now targeting the Moon as the next step in exploration beyond LEO and many already have plans for precursor robotic and human exploration. For example, ESA has championed the "Moon Village" concept since 2016 and NASA's 2018 budget includes a Lunar Exploration Campaign.

In this context, natural caves are appealing solutions to shelter humans and equipment for long-duration Lunar missions. In 2017, for example, data from JAXA's Kaguya probe revealed a 50km-long lava tube. For safety reasons, the preliminary robotic exploration of these tubes is imperative. Multi-robot systems carry the potential for greater efficiency and higher fault-tolerance, because of their ability to cooperate and inherent redundancy. Including humans into these systems is desirable to mitigate the complexity of the system but challenging at the interface level.

Creating a "symbiotic human and multi-robot planetary exploration system" requires tackling multiple open research questions at once. First, the coordination of several (semi-)autonomous robots is challenging because of their hard-to-predict collective emerging behaviour. Second, human-robot interaction is a relatively young discipline, even more so for multi-robot systems. Finally, in the context of caves and planetary exploration, ensuring reliable communication is entirely non-trivial.

Herein, we describe a software infrastructure which aims to address these problems. We also lay out our plans for its deployment in multiple robotic setups with increasing levels of realism. The goal is to create a semi-autonomous multi-rover system capable of exploring the Moon's surface and lava tubes under an astronaut's *in-situ* supervision. At the same time, the robots shall also place themselves so that network connectivity is preserved. One additional requirement is the low cognitive load of the human-(multi-)robot interface.

The project is a Networking Partnering Initiative between ESA's European Astronaut Centre (EAC) and Polytechnique Montreal. Its first step is the implementation of the algorithms and protocols required for exploration and connectivity maintenance. All coding exploits Buzz—a multi-robot domain-specific scripting language developed at Polytechnique. Verification is done through simulation using the multi-physics, open-source simulators ARGoS and Gazebo. The mock-up human-(multi-)robot interface is evaluated in a laboratory setup, with real robots—using Polytechnique's fleets of wheeled K-team KheperaIV and Zooids. The system methodology developed in this project will potentially lead to deployment within ESA analogue campaigns and facilities (such as the LUNA facility at EAC).