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AUTOMATED MULTIDISCIPLINARY DESIGN AND CONTROL OF HOPPING ROBOT SWARMS FOR EXPLORATION OF EXTREME ENVIRONMENTS ON THE MOON AND MARS

Abstract

The next frontier in solar system exploration will be missions targeting extreme and rugged environments such as caves, canyons, cliffs and crater rims of the Moon, Mars and icy moons. These environments are time capsules into early-formation of the solar system and will provide vital clues of how our early solar system gave way to the current planets and moons. These sites will also provide vital clues to the past and present habitability of these environments. Current landers and rovers are unable to access these areas of high interest due to limitations in precision landing techniques, need for large and sophisticated science instruments and a mission assurance and operations culture where risks are minimized at all costs. Our past work has shown the advantages of using multiple spherical hopping robots called SphereX for exploring these extreme environments. Our previous work was based on performing exploration with a human-designed baseline design of a SphereX robot. The design of SphereX is a complex task that involves a large number of design variables and multiple engineering disciplines. In this work we propose to use Automated Multidisciplinary Design and Control Optimization (AMDCO) techniques to find near optimal design solutions in terms of mass, volume and power for SphereX for different mission scenarios. The implementation of AMDCO for SphereX design is a complex process because of complexity of modelling and implementation, discontinuities in the design space, and wide range of time scales and exploration objectives. Moreover, the design of SphereX will depend on target environment (e.g. Moon, Mars), coordination complexity with increased number of robots, expected distance of exploration and expected mission length. We address these issues by using machine learning in the form of Evolutionary Algorithms to search through the design space and find pareto optimal solutions for a given mission task. Using this design process it is possible to find creative solution not thought of the by the experimenter. Our earlier efforts applied to excavation robots found controllers that were human-competitive or better. The modeled disciplines are propulsion and attitude control for mobility through ballistic hopping, power consumption, energy storage, and communication. Multiple SphereX will enter a lava tube through collapsed ceiling entrance and perform coordinated exploration to rapidly form 3D maps of the environment using state-of-the-art SLAM techniques. Using this technology it is now possible to perform end to end automated preliminary design of planetary robots for surface exploration.