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EXPLORING LUNAR CAVES WITH A TELEOPERATED FREE-CLIMBING ROBOT

Abstract

Since their discovery in 2009, lunar caves have shown immense potential for space exploration, holding the promise of valuable scientific discoveries. However, their complex and rugged terrains remain a major challenge for conventional wheeled rovers. To address this, we have developed XCLIMBER—a four-legged climbing robot specifically designed to scale vertical rock surfaces and traverse diverse terrains. Its limbs consist of 4-degree-of-freedom (DOF) joints arranged in an insect-like configuration. XCLIMBER is equipped with stereo cameras enabling an operator to select target handholds using camera images and force/torque sensors to adjust gripping forces during operation. Its control system architecture employs a human-in-the-loop approach consisting of a high-level controller for mode and handhold selection and a low-level controller for robot positioning and gripper control. The preliminary experiments conducted in a simulated lunar environment showed that XCLIMBER can effectively climb vertical walls made from limestone surfaces. Its spine grippers can adapt to varying terrain features and maintain stability during operations. These results highlight the potential of XCLIMBER as a reliable tool for exploring challenging extraterrestrial environments such as lunar caves.