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Video Presentation of a Rock Climbing Robot

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***Abstract*— JPL has developed the worlds first rock climbing robot. This video presents climbing trials at vertical, overhanging, and inverted angles, and a zero-g drill for astronauts.**

In past work, we showed hand-actuated rock grippers using microspines[1], a kind of claw [2], [3]. These grippers have been upgraded and integrated with the LEMUR IIB robot [4], [5]. Each gripper is now controlled by two actuators. A deployment actuator holds the claws away from the surface. When released, torsion springs push the claws into the rock. An engagement actuator drags the claws inwards through a network of springs that allow the claws to independently find rough spots to grip. Two actuators control over 750 claws. Using hierarchical compliance, microspines conform to mm-scale roughness, carriages conform to cm-scale, and the robots limbs conform to 10-cm scale. A gripper can support 150N in any direction on rough volcanic rocks, and supports 50-75 N on semi-rough or friable rocks. Very smooth rocks are likely to be found only on Earth.

Open-loop climbing experiments were performed on vertical, overhanging, and inverted rock faces. Like planetary rovers, the robot moves slowly and carefully, prioritizing safety over speed. With 3 degrees of freedom per limb, the robot is kinematically constrained to relatively flat rock. For inverted trials, 15 lbs of gravity offload was also needed to compensate for sag in the compliant system. Future JPL systems like LEMUR 3 and RoboSimian will traverse almost any rock geometry and will not need sag-compensation.

Prototypes with two hall-effect sensors on each carriage provide both magnitude and distribution information on a grip. Combining these data with the stereo vision from LEMUR's cameras will enable long duration autonomous climbing using closed-loop control in future trials.

Previously, we showed a rotary-percussive drill that used offboard power and control with a hand actuated gripper [6]. We have upgraded this system to a self-contained power-tool for astronauts. The gripper now uses a robotically driven triple lead screw to engage the rock, while keeping the center of the gripper clear for the drill bit to pass. Rock cores can be acquired in zero g by a heavily gloved hand.

One day, this technology could help explore asteroids and set up safety cables for astronauts. The climbing robot and drill also have applications to crater walls, cliff faces, and lava tubes on Mars and the Moon, and could provide mobility for Phobos/Deimos missions.

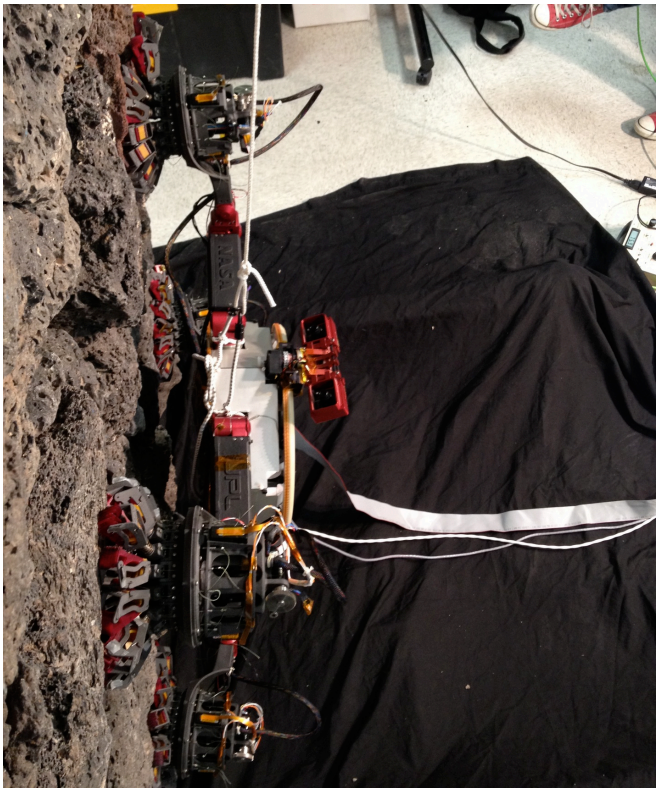

Fig. 1: LEMUR IIB climbing a 15° overhanging rock wall.

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