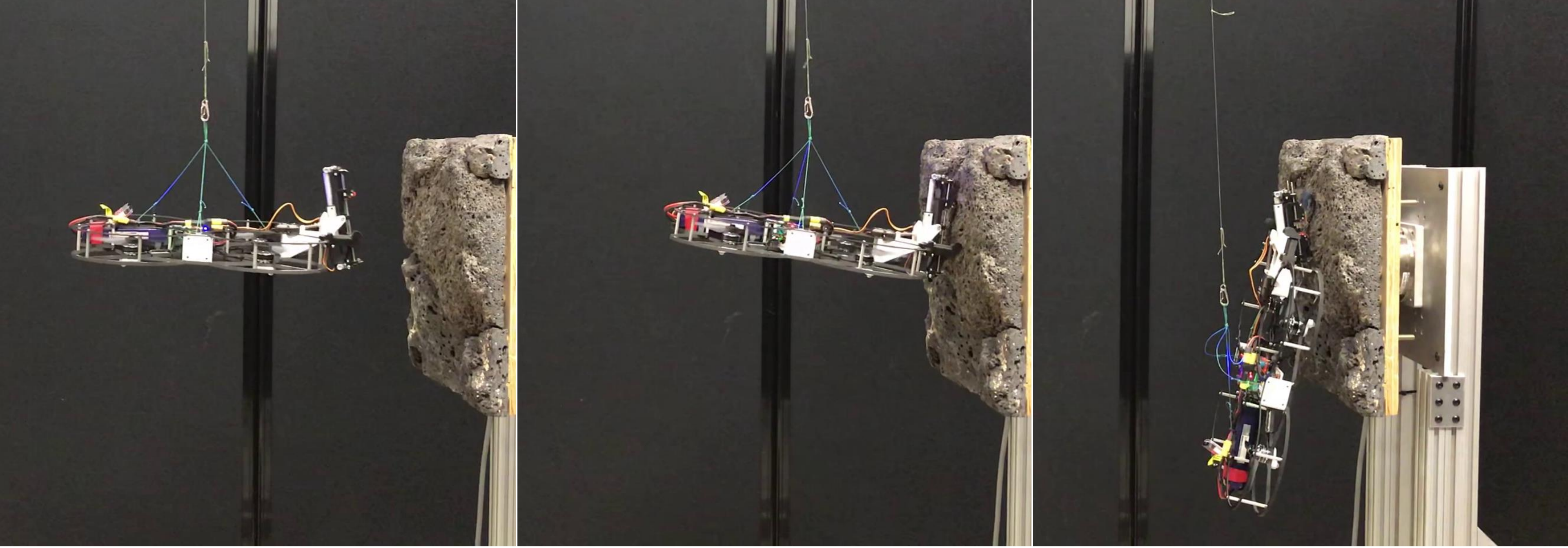

Virtual Research Presentation Conference

An Ultra-Light Weight Perching System for Sloped or Vertical Rough Surfaces on Mars

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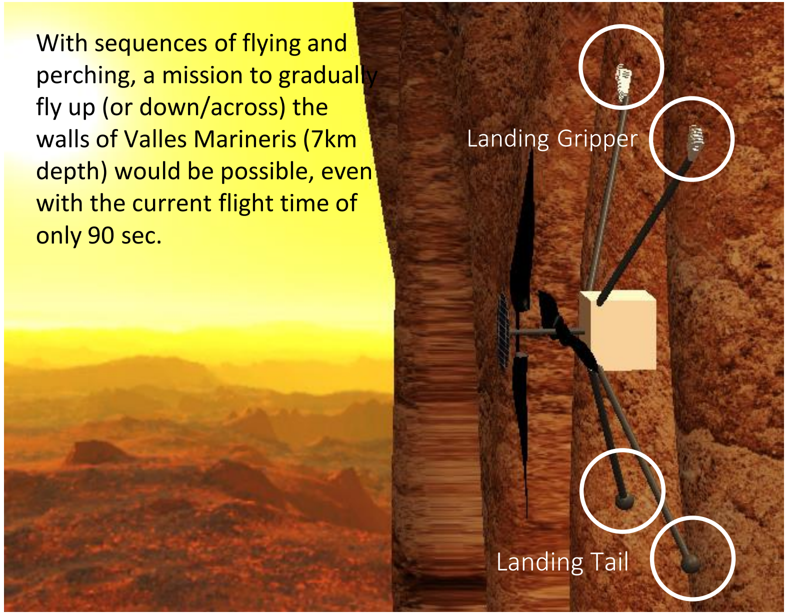
Program: Topic RTD

Assigned Presentation # RPC-262

Jet Propulsion Laboratory
California Institute of Technology

Introduction

- Steep slopes are often associated with geologically and astrobiologically interesting features which can't be accessed with traditional rovers but are accessible by aerial vehicles
- We are more than ever close to flight over space bodies other than earth in the solar system with Mars 2020 Helicopter tech demo.
- Martian environment severely limit rotorcraft flight times; the current Mars Helicopter can fly for only 90 seconds per charge.
- Most scientific instruments require close contact with the target surface
- Perching system enable close contact of science instruments with steep surfaces while aerial vehicle is at rest and can recharge the batteries.

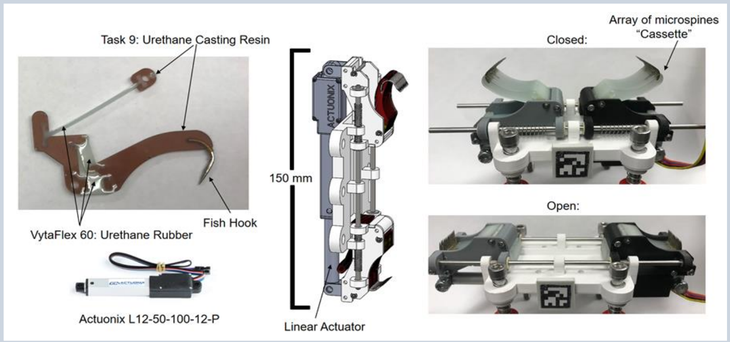


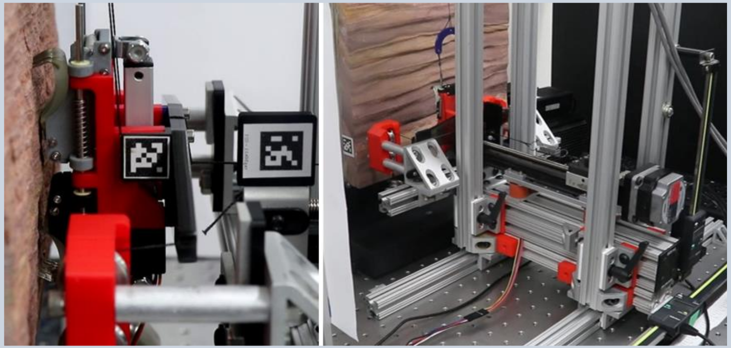
Problem Description

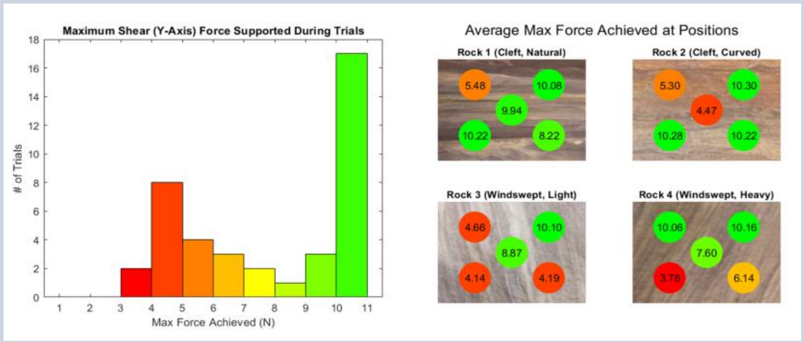
- Developing an ultra-light weight (<10% of total system mass) perching system to enable a Martian flying vehicle to perch on steeply sloped or vertical walls.
- A future Mars lander or rover to detect an area of interest near the primary mission site on a steeply sloped or vertical surface, deploy the flying system to perch and investigate the target, or to extract and return samples back to the lander/rover.
- The developed perching system can be adapted by other flying systems (free-flyers, CubeSats, etc.) to perch onto surface of comets, asteroids, the Moon or Phobos to study the surface, extract samples, and recharge batteries.
- Perching systems for rotorcraft and fixed-wing aerial systems have been explored by a few academic groups for smooth and man-made rough surfaces on Earth, including demonstrations by the PI, [Kalantari et al., ICRA 2013], [Daler et al, 2013], [Desbiens et al. 2011].
- The Martian environment, including potentially dust covered surfaces, and the anticipated low payload capability of the flight system, impose severe constraints for traditional perching systems and present additional challenges beyond current state-of-the-art perching mechanisms.

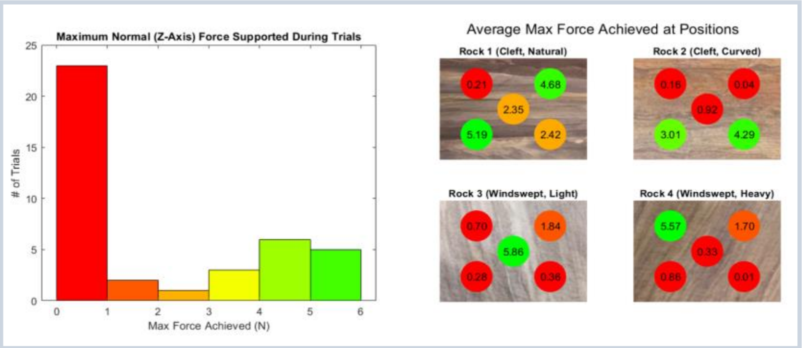
Gripper Design and Prototype

Designed, fabricated prototype, and characterized performance of a compact and lightweight gripper



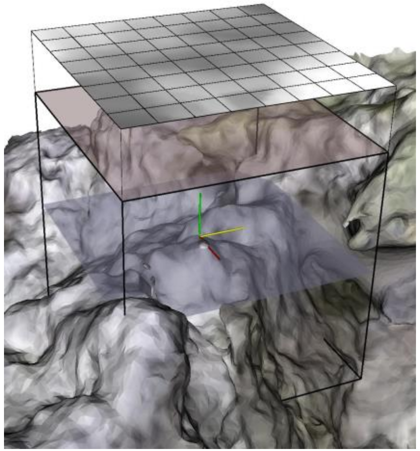






Perch-ability algorithm

- The gripper testing results suggest certain surface shapes (e.g., concavities) and textures (e.g., smooth surfaces) are adversarial and will often lead to a grasp failure.
- To maximize perching success, an image-based grasp model is developed, which enables measuring the perch-ability of arbitrary sites.
- The task of this model is complex to enumerate and classify with a rule-based system and well-suited for a data-driven model
- The model is based on convolutional neural network (similar to LeNet [LeCun et al., 1998]) grounded in a locally-tangent depth map.
- The model takes an RGBD image as input, and it outputs a suitability score for a grasp that aims at the site shown at the center of the image.

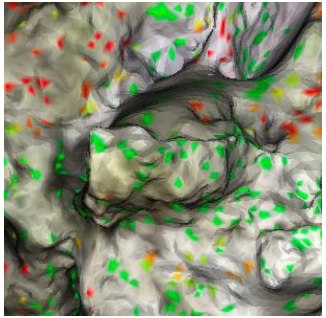


locally-tangent depth map, input to the perch model. Brighter pixels correspond to surfaces that are further into the rock wall.

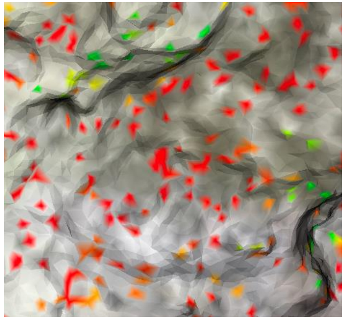
Perch-ability algorithm

- The rock data was obtained during a field trip at Pisgah, CA.
- Rock surface mesh was created with a structure-from-motion toolbox and a few dozen cell-phone images of relevant rock walls.
- Model is trained on expert-annotated data: manually outlined suitable or unsuitable areas on a high-quality rock mesh.

Output of the perching model. Green and red dots show suitable and unsuitable sites, respectively.



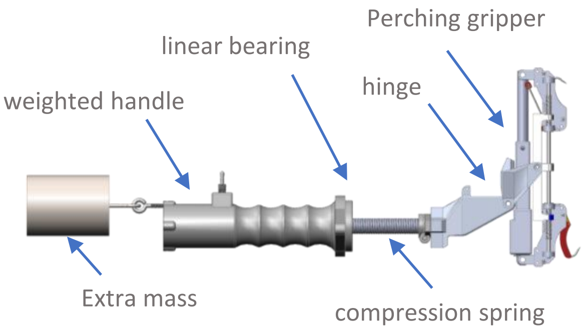
Convex area correctly classified as suitable.



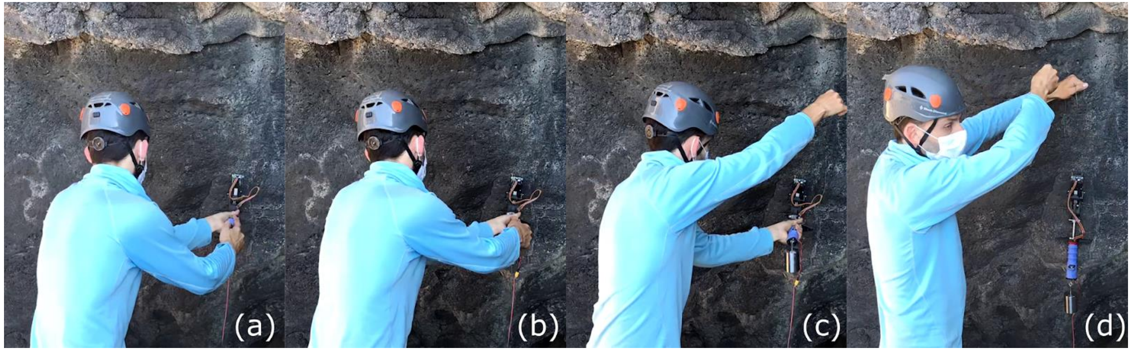
Concave area correctly classified as unsuitable

Perch-ability algorithm

- Perch-ability was tested on 24 sites with a hand-held version of the perching gripper, and captured an RGBD image of each grasp site using Intel RealSense D435 RGBD camera.
- Grasp success was established via a dead mass representative of the copter.
- Grasp success/failure was recorded along with the captured RGBD image to automatically annotate the data during post processing.



hand-held version of the perching gripper

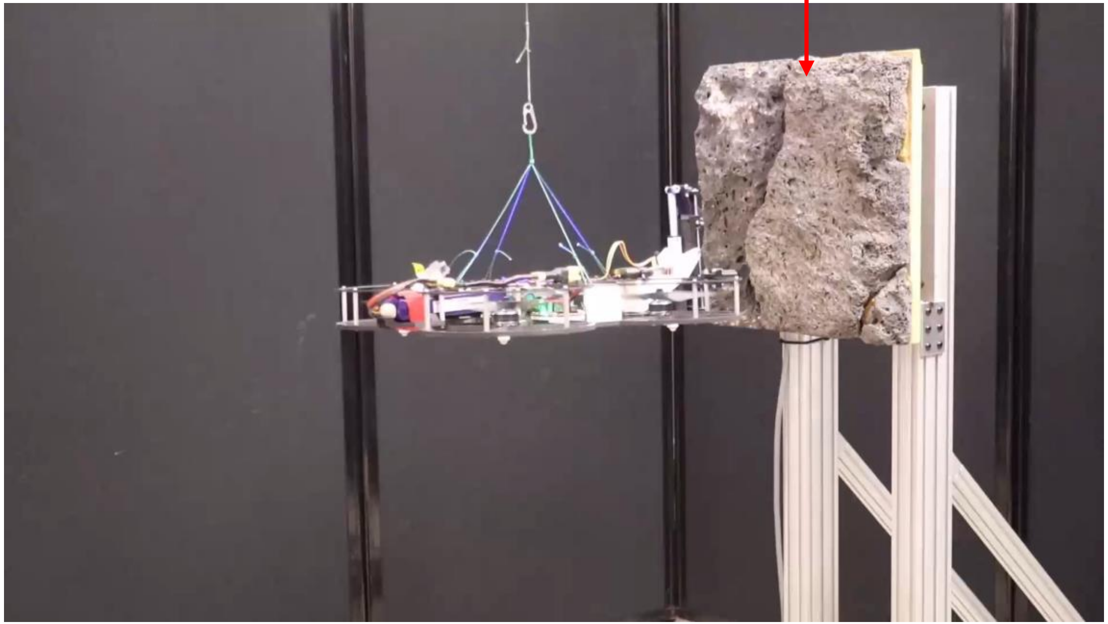


Handheld operation of the gripper at Pisgah, CA: the gripper positioned, gripper engaged(b), the handle rotated downward (c), and handle released (d). The success of the grasp was verified by the gripper supporting 1.5 kg.

Perching Test

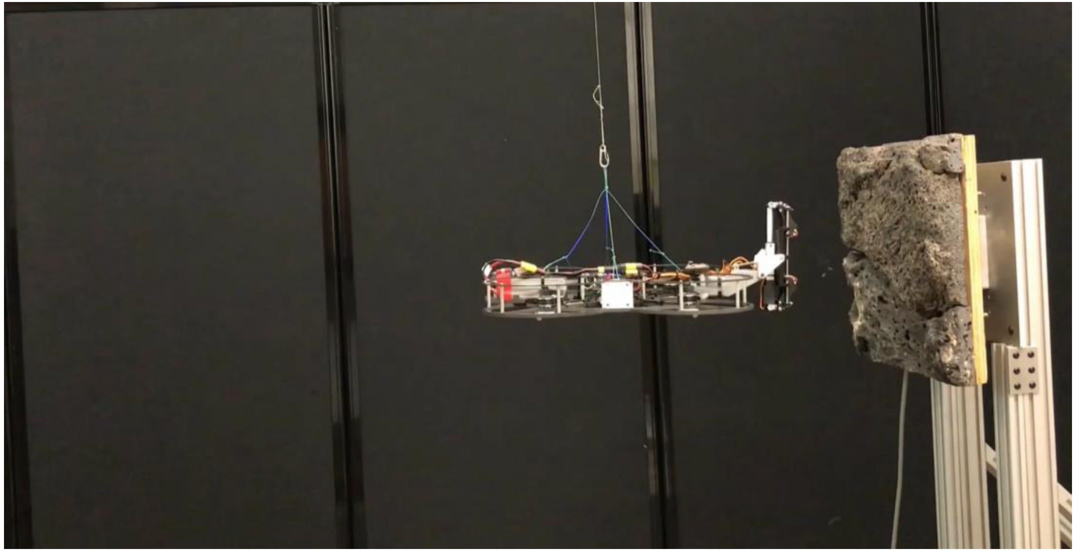
- Demonstration of successful perching in a tele-operated flight.

Vesicular basalt mounted on force-torque sensor



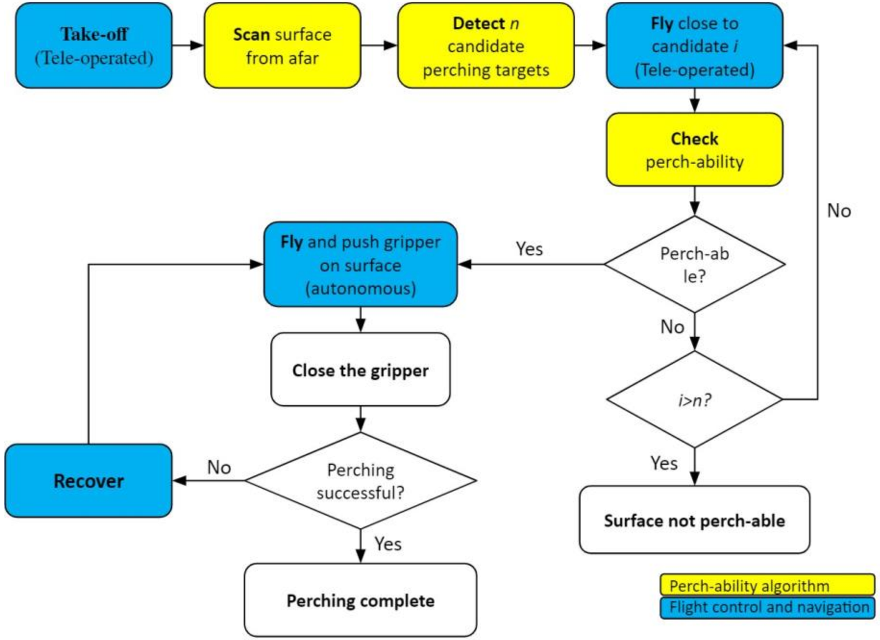
Detachable Gripper

- An alternative concept of operations for the system could involve the vehicle using the gripper to place an instrument at a target of interest instead of the whole vehicle perching.



Flow chart of a flight and perching mission

- Next steps: Perch-ability detection and autonomous perching algorithms will integrated on flight platform and semi-autonomous perching maneuver will be experimentally tested based on following flow chart.



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