Co-Robotic Systems for GeoSciences Field Research

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Summary

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The goal of this project is to integrate environmental science, robotics, and cognitive science to enable heterogeneous teams of autonomous robots to flexibly support the daily agenda of teams of geoscientists in their field experiments. Environmental sciences concerning desertification and sediment loss present urgent social value. Due to the high spatial and temporal variability of the driving and resistance forces during sediment transport, novel high-resolution and event-driven data sets are requried to enhance existing and new empirical and theoretical models of such dynamic process. Legged robots have demonstrated great potential of using legs as embodied sensors to provide such novel datasets, while the imperative for useful, autonomous mobile manipulation in unstructured, broken and unstable natural terrains drives fundamental advances in the theory and practice of robotics. In the meantime, growing insight from cognitive science concerning human spatiotemporal reasoning urges its engagement in a new frontier of real-time, perceptually mediated decisions epitomized by scientifically motivated outdoor field research on the motion of waters, winds and sands.

Environmental science: Robot legs as embodied sensor to provide novel dataset for geosciences

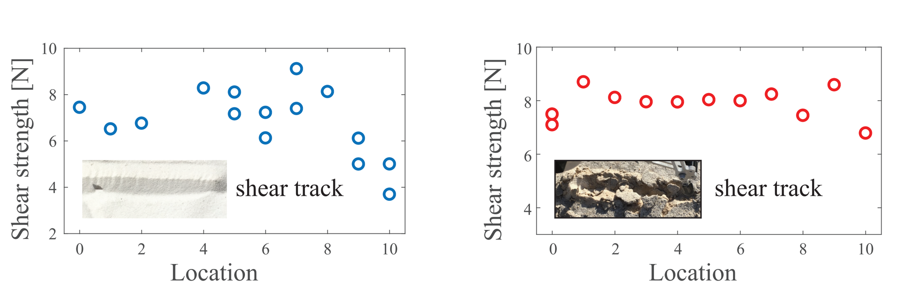
Gypsum dunes (White Sands, NM)

Hillslope-River (Wissahickon, PA)

Quartz sand dunes (Oceano, CA)

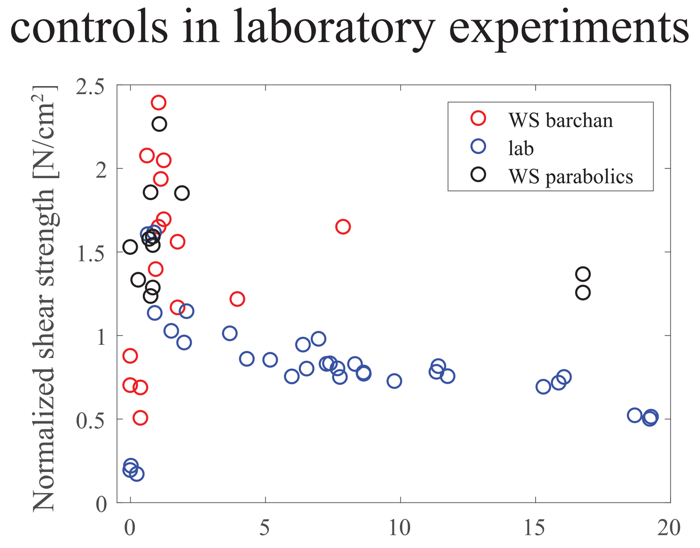
We develop novel geoscientific instrumentation embodied in robots' limbs, and deploy the semi-autonomous robot at White Sands, NM, Oceano, CA, and Wissahickon, PA to characterize the mechanical properties of soil that determine its resistance to erosion and transport by overland flow and creep. Such information is critical in understanding sediment loss to wind and rivers, and provides insights on soil stability in landslides and desertification processes.

Spatial variation and environmental controls of soil erodibility



arid barchans: soil moisture dominant
vegetated parabolics: surface crust dominant

Isolating dominant environmental controls in laboratory experiments



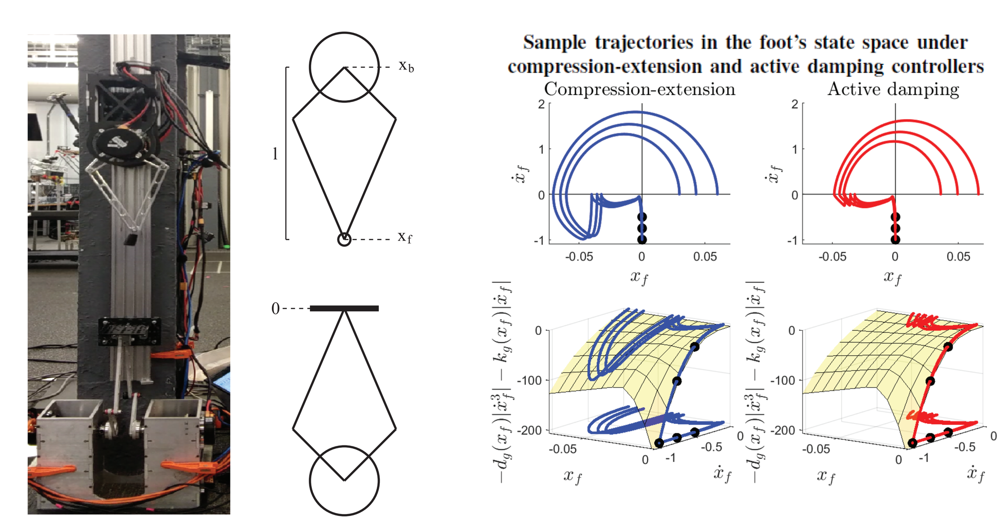
Qian et al., *Aeolian Research*, 2017
Qian et al., *Journal of Geophysical Research: Earth Surface* (in review)

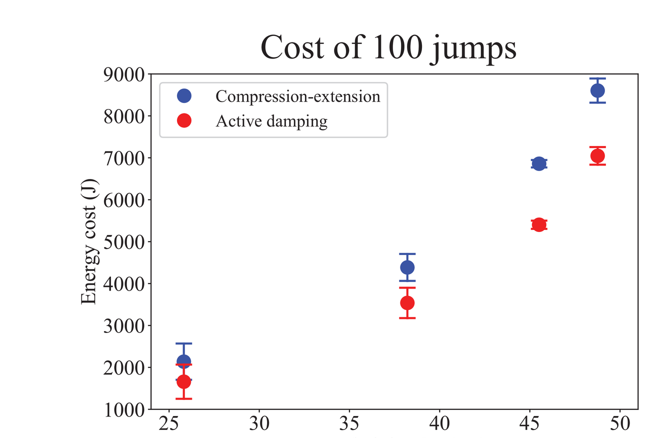
Robotics: Robot locomotion in unstructured and unstable natural terrains

Locomotion challenges

-- Deformable terrain (sand, gravel, leaf litter)
-- Obstacle (rocks, boulders, fallen trees)
-- Entangling vegetation (grass, stems)

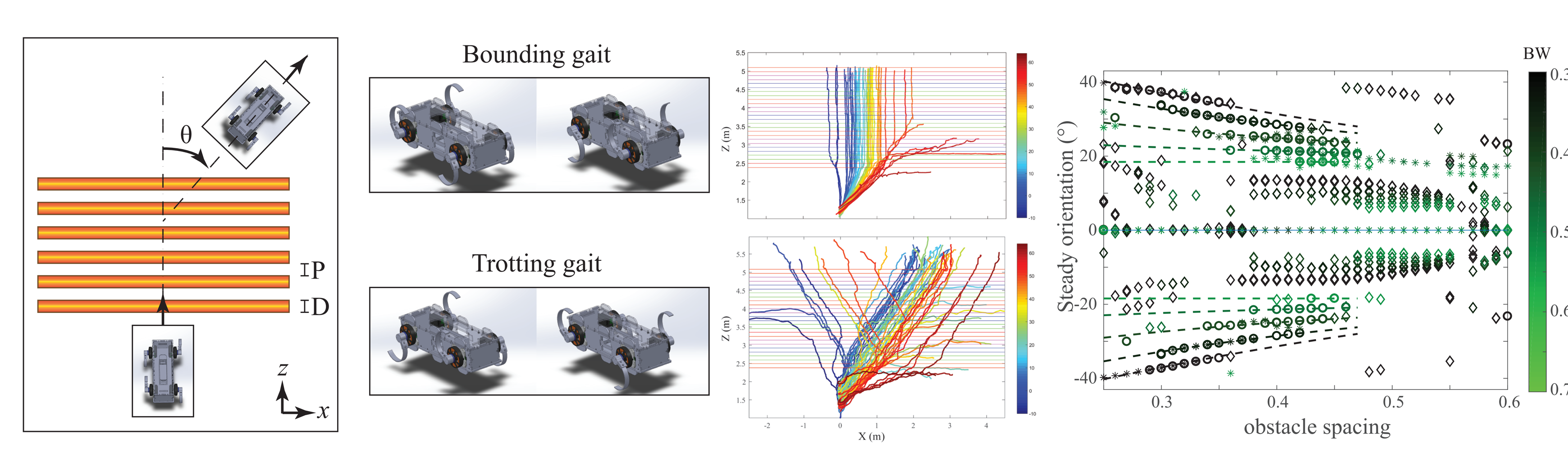
Dynamic hopping on granular media





Roberts and Koditschek, *IEEE ROBIO, 2018* (accepted)
Roberts and Koditschek, *ICRA 2018* (in review)

Obstacle-aided locomotion



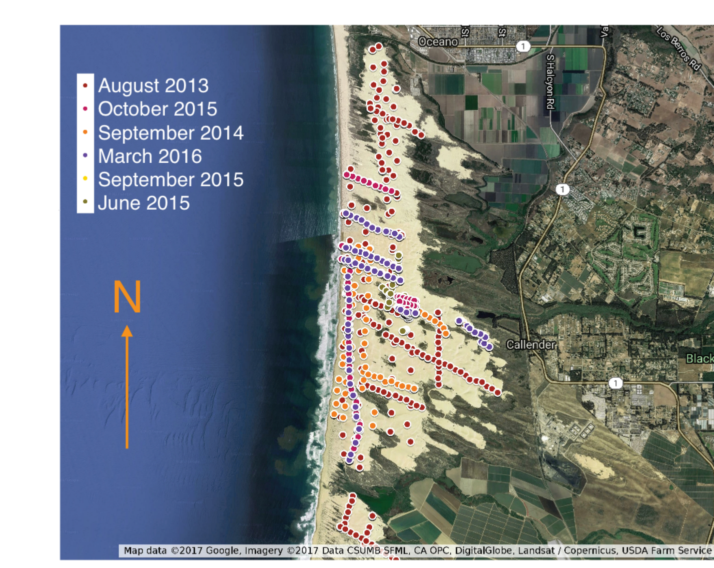
Cognitive science: Real-time decision making and human-robot collaboration

We explore the human decision-making process during field data collection, and seek to employ such knowledge to improve the effectiveness of our collaborative robots and inform best practices in geoscience field research.

How do experts make decisions about where to collect data?

Two levels of location selection:

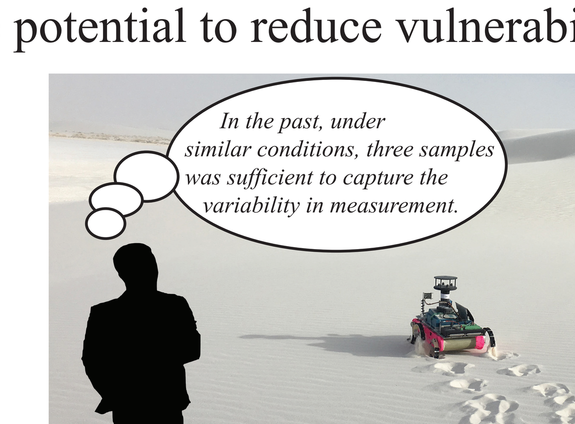
1. Where should the transect be conducted?
   - -- Representative (ideal v. non-ideal features)
   - -- Accessible
2. Where along the slope should measurements be taken?
   - -- Based on experts perception of measurement variability

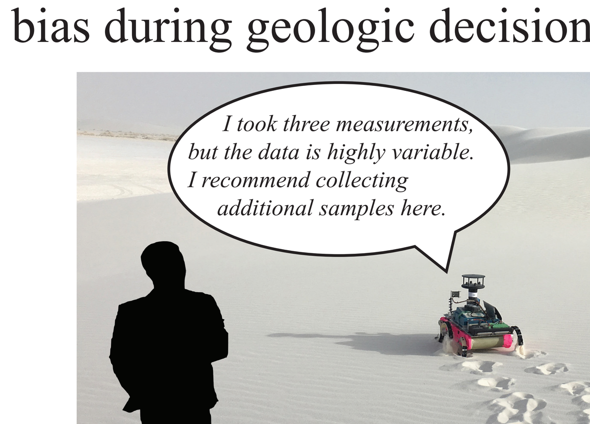


PI-SWERL measurements at Oceano, CA
data courtesy of G. Nikolich and P. B. Reverdy

How do experts resolve uncertainty during data collection?

When faced with uncertainty, decision makers rely on prior knowledge and employ heuristics. Heuristics are efficient and offer satisfactory solutions for most decisions, but can sometimes yield less-than-optimal choices, referred to as *decision biases*. In-situ measurement feedback from robotic platforms has the potential to reduce vulnerability to bias during geologic decision making.





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