Poster #EP43A-0965

Robotic measurement of aeolian processes

Sonia Roberts [1] Douglas Jerolmack [2] Nick Lancaster [4] George Nikolich [4] Paul Reverdy [1] Thomas Shipley [3] Scott Van Pelt [5] Ted Zobeck [5] Daniel E. Koditschek [1]

[1]University of Pennsylvania, Electrical and Systems Engineering [2]University of Pennsylvania, Earth and Environmental Science [3]Temple University, Department of Psychology [4]Desert Research Institute [5]USDA-Agricultural Research Service, Wind Erosion and Water Conservation Research Unit, Lubbock/Big Spring, TX

Summary

Measurements used to study wind shear stress and turbulence, surface roughness, sand flux, and dust emissions are typically obtained from stationary instrumentation, and are thus limited spatially. They are also dependent on deployment of instrumentation for specific events and thus the are limited temporally. We have been adapting a rough-terrain legged robot capable of rapidly traversing desert terrain to serve as a semi-autonomous, reactive mobile sensory platform (RHex [1]), which would not share these limitations. We report on early trials of the robotic platform at the Jornada LTER and White Sands National Monument to test the feasibility of gathering measurements of airflow and rates of particle transport on a dune, assessing the role of roughness elements such as vegetation in modifying the wind shear stresses incident on the surface, and estimating erosion susceptibility in an arid soil. The robot not only serves as a mobile platform for science instruments; it can also perform controlled "kick tests" to locally examine soil strength. We outline a strategy for mapping soil erodibility and its controlling parameters using the unique capabilities of RHex, and the implications for understanding erosion and dust emission from complex terrain.

Robot and study environments

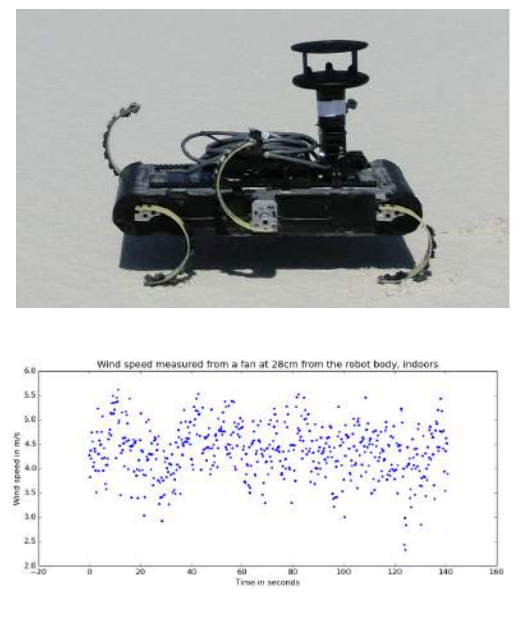
RHex has excellent and robust locomotion capabilities over rough terrain, with a full computer on board which can be used to take data from a wide variety of sensors. We have tested RHex for mobility in White Sands National Monument (New Mexico), the Jornada Experimental Range (New Mexico), and Little Dumont Dunes (California).

(a) RHex at White Sands National Monument, and White Sands (NASA; photographed from the ISS)

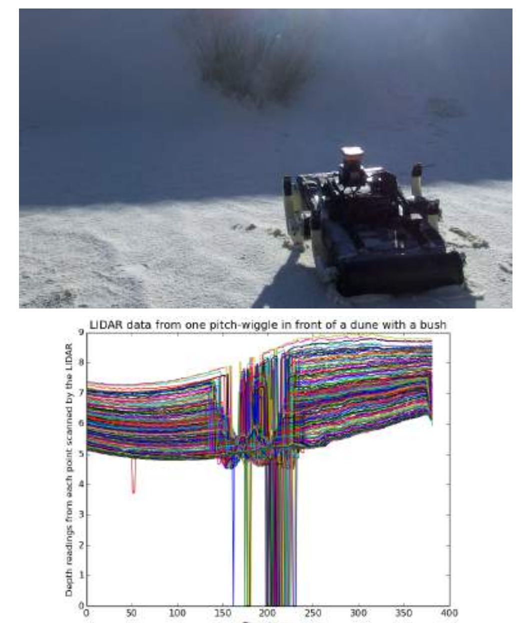
(b) Jornada Experimental Range (top) and Little Dumont Dunes

In some study locations, most notably White Sands, plumes of dust arise from emissions that are localized in space and time. Grain-scale measurements are needed to complement remote sensing data. The effects of vegetation elements on dust transmission, measured at the grain scale, is of particular interest.

Sensors and example sensor configurations



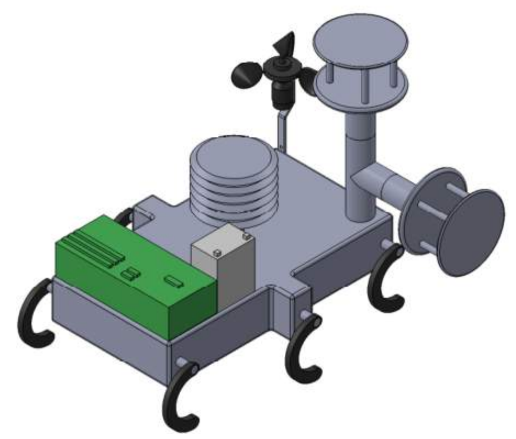
(a) Anemometer on robot, and example data ■



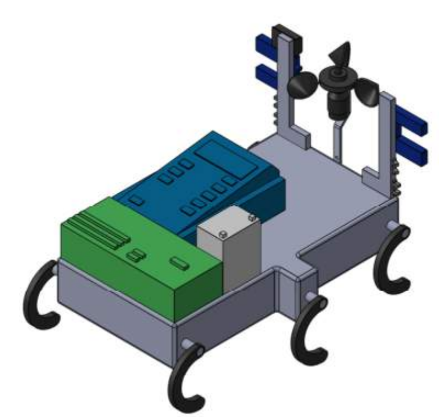
(b) Laser scanner on robot, and example reading of bush ■

(c) Downward-facing camera ■ ■ ■ ■

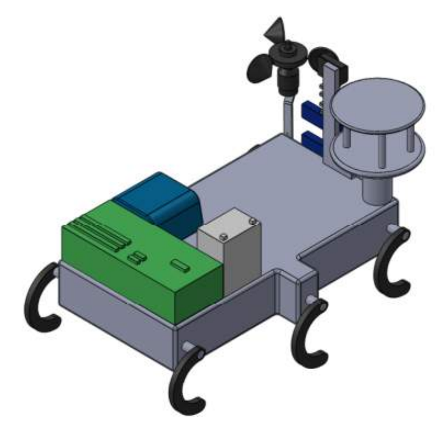
Above are three example sensor suites, with examples of the types of data that can be gathered, used during preliminary experiments in fall 2014. Below, we list three proposed sensor configurations for an upcoming trip in March.



(a) Wind and meteorological ■ ■ ■ ■ ■



(b) Sand and dust ■ ■ ■ ■ ■ ■



(c) Wind and sand hybrid ■ ■ ■ ■ ■ ■ ■

Sensor list

- ■ Gill WindSonic1 2D Sonic anemometer with RS-232 output X2
- ■ RM Young Model 03101 cup anemometer
- ■ T/RH Probe CS215 with radiation shield
- ■ Pyrometer CS300
- ■ TSI DustTrak 8520 PM10/PM2.5 dust instrument
- ■ Wenglor model YH03PCT8 optical gate as saltation sensor
- ■ Optek OPB800 optical gate as saltation sensor
- ■ Sharp Dust Sensor dust and fine sand sensor
- ■ Datalogger CR1000 and custom DRI high frequency datalogger
- ■ Hokuyo UTM-30LX laser scanner
- ■ GoPro Hero 3 camera

Research questions

- Relationships amongst surface conditions (e.g. soil texture, moisture content, roughness), wind shear stress, and dust emissions from natural and anthopogenically-disturbed surfaces?
- Spatial and temporal pattern of sand transport on the stoss slope of desert sand dunes?
- Predictions of shear stress distributions on a simple flat non-erodible surface by roughness element density, porosity, and flexibility?
- Predictions of surface shear stress distributions and soil particle entrainment patterns in a heterogeneous shrub community by topography, vegetation basal coverage, vegetation height, vegetation porosity, vegetation flexibility, wind direction, and wind speed?
- Temporal and spatial uncertainties in the 3-D wind fields and shear stress distributions near individual roughness elements of various size, porosity, and flexibility?
- Effects of roughness element distribution patterns and complex vegetation patterns on the surface patterns of shear stress distributions?
- Particle movement as a function of wind speed and direction in vegetated environments?

New datasets

- High temporal (1 Hz) and spatial resolution (< 1m) real-time measurements of surface conditions, wind shear stress, sediment transport, and dust emissions on a variety of desert surfaces (natural and anthropogenic), before, during, and after dust events.
- High temporal (1 Hz) and spatial resolution (1m) event-based measurements of sand transport and wind shear stress on desert dunes.
- High spatial resolution measurements of wind shear stress and sediment transport in vegetated dune and sand sheet landscapes.
- 3-D microscale wind fields and shear stress distributions around artificial roughness elements.
- 3-D wind fields and shear stress distributions around coppice dunes and isolated vegetation elements.
- Locations of dust emissions during erosive wind events can be identified within small landscapes by following gradients of optical occlusion.
- Surface characteristics which can be remotely sensed and measured.

Acknowledgments

This work is supported in part by NSF INSPIRE Award 1514882, "Legged Locomotion for Desert Research." The authors would like to thank the DRI and USDA for the use of its facilities, Shiv Dalla and Lawrence Gardner for manufacturing and experimentation, and Diedra Krieger for administrative assistance.

[1] G. C. Haynes, et al., "Laboratory on legs: an architecture for adjustable morphology with legged robots," in SPIE Defense, Security, and Sensing, pp. 83870W-83870W. International Society for Optics and Photonics, 2012. doi: 10.1117/12.920678