Wind-driven Rovers for Exploring Vast Expanses of Mars

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Abstract
In order to maintain continued robotic space exploration to Mars, future rovers must conform to the criteria of low cost, low power requirements, ability to travel vast expanses, ability to be deployed from a small package, and ability to take advantage of *in-situ* resources. Wind powered movement is a prime candidate for an alternate mode of transportation because there is sufficient wind on Mars (Lorenz 1996) and the rover power and drive train systems could be significantly smaller, less massive, and require less energy than conventional rovers (Antol et al. 2003). Using the design inspiration of biological robotics, an earth analog which has the ability to travel large distances over rough terrain solely on wind power is the Russian thistle, or tumbleweed.

Project Objectives
The scope of this project deals with two different aspects of tumbleweed rover technologies. The first is the evaluation of three different design concepts: the sphere, the dandelion, and the box-kite for the aerodynamics and maneuverability properties. This means determining the drag coefficients and testing the models in a rock field to see their ability to maneuver obstacles. The second part of the project is to use another biologically inspired concept of swarming or group algorithm. If a group of tumbleweeds were to explore the surface of Mars would they be able to transverse across a rock field and still be able to remain in contact. This requires a randomized abstract simulation of how a tumbleweed would cross a rock field with an algorithm that would evaluate each rover and tell it how to steer (in the real life model steering would be accomplished by shifting the center of mass of the tumbleweed).

Methodology Used
Three designs were used as possible potential tumbleweed configurations. Given that the planned diameter of the Martian rover is 5 meters and there is an average wind speed on Mars of 7 m/s, using the properties of the Reynolds number similar to conditions on earth would be a wind speed 2.6 m/s with a scaled diameter of .0762m (6 inches). The drag coefficients and rock field measurements were taken on a low speed wind tunnel (0m/s-3m/s). Hanging the model rover from a string attached to the top of the wind tunnel, displacements due to the wind speed could be measured. Using this measurement, free body diagram analysis, and the equation of the force of drag, the coefficient of drag could be determined. The ability to traverse obstacles will be tested by setting up an obstacle, a beam of varying heights, and testing the models to see if they will be able to navigate the obstacle successfully.

For the abstract rock field simulation, the simulated rock field used was based on an exponential fit of size-frequency distribution of rocks in view of Viking 1 (Golombeck and Rapp, 1997)

$$N(D) = 3.82e^{-3.38D}$$

Where D is the diameter of the rock and N(D) is the number of rocks per square meter. When a rock encounters a rock it will either not affect the rover, be fully navigable, be partially navigable, or not be able to be traverse at all. This is determined by the h_{max}, or max allowable height of the rock which is determined by a moment balance at the obstacle.

$$h_{\max} = r(1 - \sqrt{\frac{(mg_{mars})^2}{(C_d(\pi r^2)(\frac{1}{2}\rho V_{wind}{}^2)) + (mg_{mars})^2}})$$

The simulation was written using a Gaussian randomization of parameters, which includes wind speed, rock height, velocity affect of rock on the rover, and deflection angle from navigating the rock. The simulation was distance dependent so each time the rover traveled a meter; the code ran a check to see if there was a rock and if so what the height was. The swarming algorithm was an influenced based code. The rover would check for rovers in the communication range, see if the distance was too far or too close than desired, then taking the average of the rovers distances would steer by shifting the center of weight towards the appropriate direction.

Results Obtained

The figures below show the path rovers of different radius would travel. Changes in the y–coordinate show the frequency in which the rover was encountering a rock or steering to maintain appropriate spacing. Preliminary drag coefficients were determined and further testing will be done to confirm the accuracy.

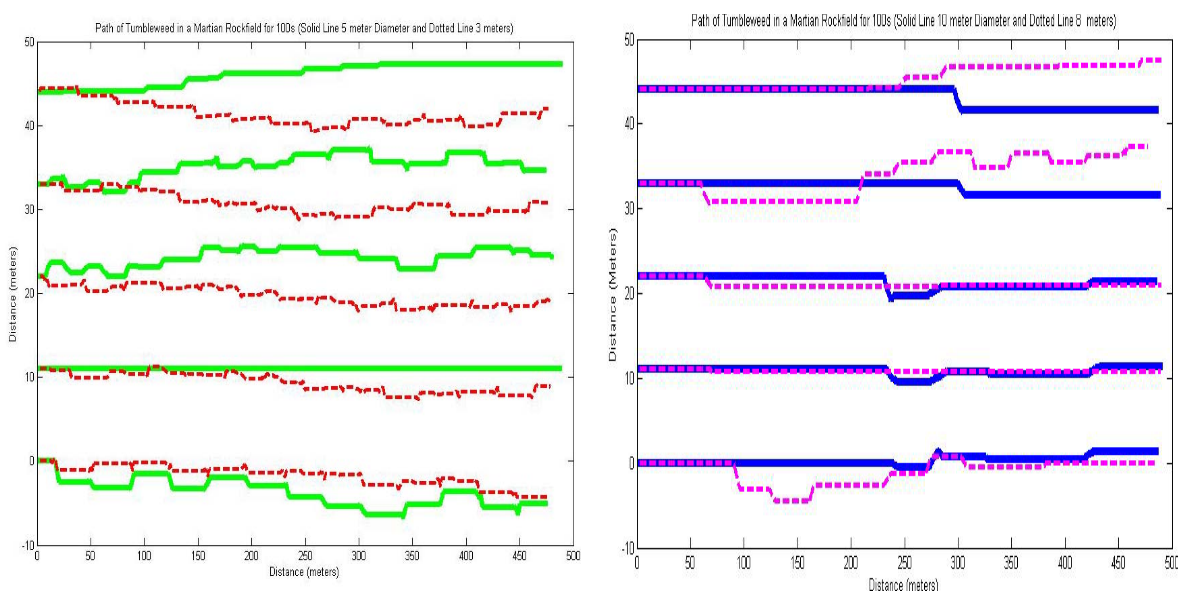

Figure 1. How different diameter affects interaction with the rock field

References

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