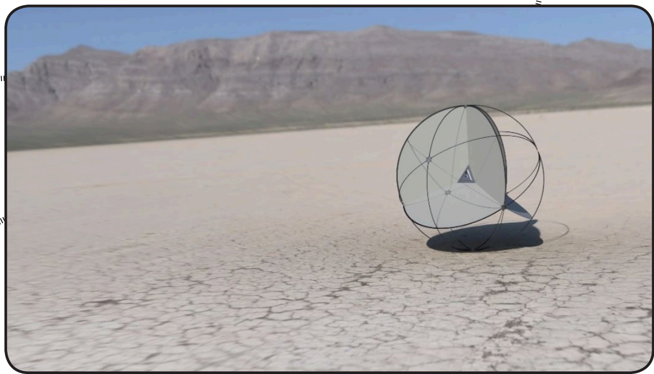
The Tumbleweed Mars Rover

Large-scale surface exploration on Mars.
Pre-selecting research targets.
Cost-, time-, and energy-efficient.
Powered by wind and sun.

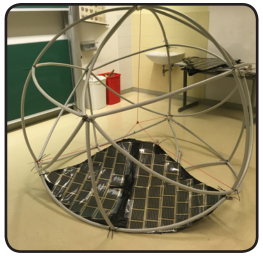
@team.tumbleweed

http://teamtumbleweed.eu

BÖHLER SCHMIEDETECHNIK



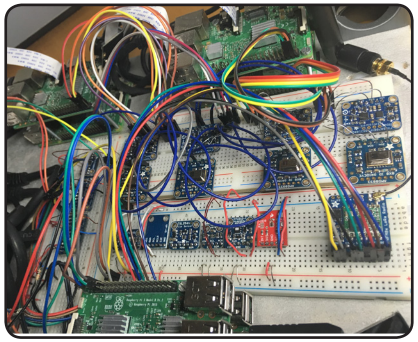
ENERGY



12 m² organic solar cells continuously provide about 60 W. 30 W is needed to power the electronics, and 30 W is used to charge the batteries. We use Panasonic Li-Pos in a 3x6 configuration, storing up to 226 Wh. They can power the Tumbleweed through the whole night since we are able to adapt power consumption dynamically by using less complicated image recognition models.

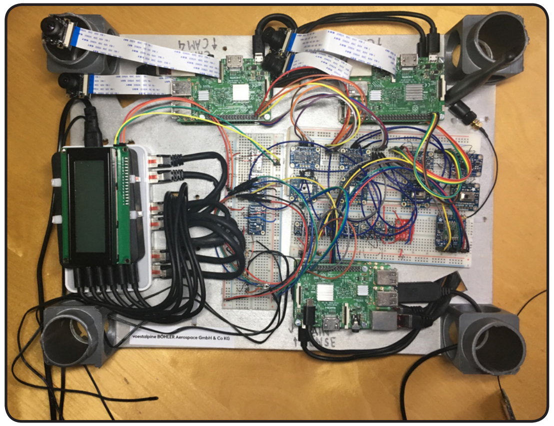
DATA

The Tumbleweed is equipped with the following sensors: 4 cameras, 4 infrared cameras, 4 gyroscopes, 4 accelerometers, 4 magnetometers, 2 thermometers, 1 hygrometer, 1 infrared sensor, 1 visible light sensor, 1 UV sensor, 1 barometer, 4 thermistors, 3 ADCs, and 1 GPS receiver. Every 6 seconds, the Tumbleweed measures all the environmental variables like temperature and pressure and takes normal and IR pictures on all four sides of the chassis. In the next step, the data is analyzed to determine if the place where the Tumbleweed is currently at contains any anomalies. For that, several regression models like elliptical regression and support vector machines are used to classify if the environmental variables are coherent with prior data. To classify the pictures, we trained an Inception3 deep neural network with 2500 pictures that the Austrian space forum took in the desert of Oman. Using Google's Tensorflow API, we can determine with 92% accuracy if there is sand, small rocks, large rocks, or plants near the Tumbleweed. The raw data and analysis results are stored internally. If the classification yields an anomaly, more measurements are taken rapidly, and the data is transmitted to the base station.



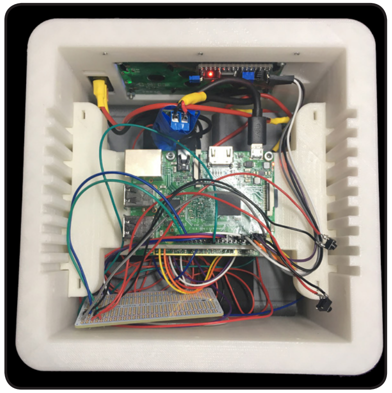
HARDWARE

Six Raspberry Pi 3 microcomputers compose the heart of the Tumbleweed. Since one Raspberry Pi alone does not have the necessary computing power to run the image and data classifiers in addition to all the other vital control functions for communication, power, etc., we distribute the responsibilities. Four of the Raspberry Pis take normal and infrared pictures. They then execute the image recognition model in parallel. The fifth performs all the other measurements and analyzes the data with our regression models. The results of all five are then transmitted to the sixth "master" Raspberry Pi. This one accumulates the data for the current location and determines via pre-defined thresholds if the results of the other computers indicate an anomaly. It is also responsible for monitoring the system temperatures, voltages, and power consumption, as well as the charge control for the battery and the communication with the base station.



COMMUNICATION

The communication between the rover and the base station is achieved by using the LoRa protocol, a low-energy, low-data, high-range standard used in internet of things applications. This the optimal way to simulate the limited data rates possible when deploying a swarm of Tumbleweeds on Mars. At the base station, we deploy a multi-channel receiver controlled by another Raspberry Pi. They are enclosed in a 3D-printed capsule that is attached to a stationary weather balloon, hovering about one kilometer above the ground to enhance the range by countering the curvature of the Earth. Inside the capsule, there are Li-Po batteries that can power it for several days. The data transmitted includes the identification number of the Tumbleweed, the location, speed, environmental variables, and analysis results. The LoRa standard is not always 100% reliable. In order to be able to decode parts of a message, even when some fractions are missing, we use flags and a corresponding dictionary to associate a value in the message with the variable it represents such as temperature. That way, we are independent of the relative position of a value in the message.



STRUCTURE

The tetrahedral structure of the Tumbleweed is the result of over 100 computational fluid dynamics simulations. We optimized the drag coefficient of the structure and achieved a value of about 1.03, over 100% more than that of NASA's related design approach. The drag coefficient is so high, that the Tumbleweeds don't even need parachutes–they can simply be dropped from the rocket. The outer arcs are currently made of composite material. They have a mechanism to collapse, shrinking by a factor of 60% and, thus, allowing for efficient transportation. The connectors are 3D-printed from titanium.