Lunar Mining: Designing a Versatile Robotic Mining System

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Introduction

The annual NASA Robotic Mining Challenge: Lunabotics tasks teams with building robots capable of traversing and mining in a simulated Lunar terrain. The competition goal is to utilize automation and sensing alongside mechanical systems to harvest icy regolith (simulated with gravel) from beneath the satellite's surface.

This year, Utah Student Robotics sought to improve upon the design from 2019-2020. The new 2020-2021 rover is still based on proven NASA concepts, such as the RASSOR 2.0 digging drum and the Rocker-Bogie mobility platform which we adopted last year and has been upgraded with new motors and custom parts to increase reliability and tighten tolerances.

Design Strategies

Our goal was to design a robot that minimized weight and power consumption. To ensure these goals were met, we performed an extensive cost-benefit analysis to determine which high-level designs would best fit our goals. Then our mechanical team used Luth-Wismer equations to calculate resultant forces and torques on different designs of our digging drum and wheels. These calculations were used to design the scoop size and grouser dimensions as well as spec. our driving and digging motors correctly.

Drum Design

Fig. 2 SolidWorks render of the drum, showcasing rounded scoops, improved filtration, and replaceable scoop teeth

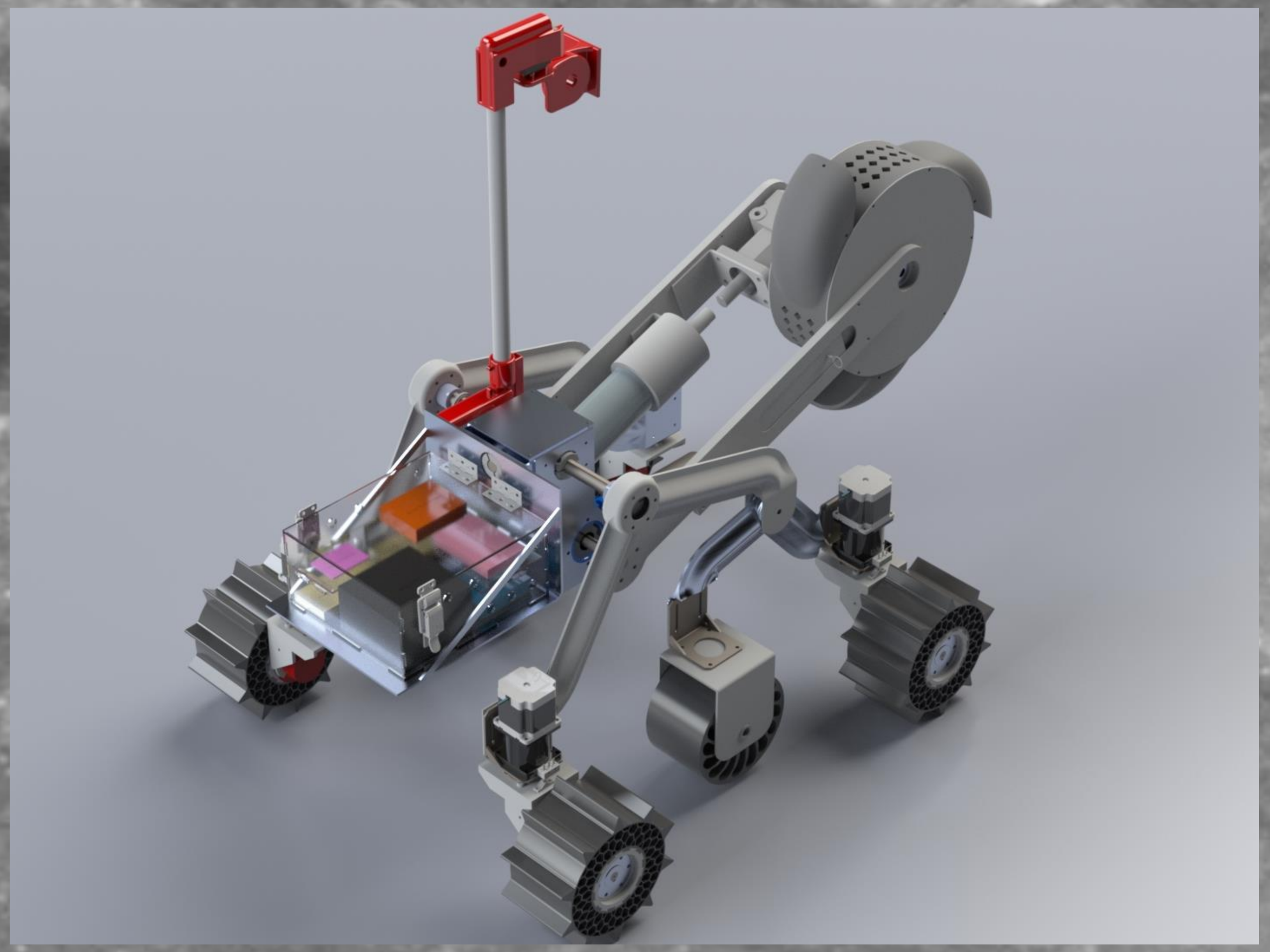

Fig. 1 Full render of the 2020-2021 robot.

Methods

Research/Trade Studies

We examined our own previous designs, robots from other schools, and solutions from NASA. We examined all the design options we had using weighted decision matrices where each option for each subsystem was qualitatively evaluated according to cost, weight, simplicity, and other such metrics.

Computer Aided Design and Manufacturing

In order to reduce the risk of having a design fail after manufacturing began, emphasis was placed on having a fully functional CAD model and PCB designs before moving on to the next phase. Each design decision was reviewed and approved by the other subteams to reduce the risk of interface conflicts.

Simulation and Testing

Before full scale models were constructed, physical prototypes were 3d printed or assembled out of more readily accessible components first. For software systems, rapid prototyping and peer-review was used to ensure component integrity. These components were then tested together in simulation to get as close to real life feedback as is possible.

Results

While the COVID-19 pandemic has presented significant obstacles to physical assembly of this year's robot, we were able to overcome those obstacles and complete construction of the 2020-2021 robot shown in Figure 1.

Mechanical

Digging and Material Collection

The mining, collecting, and depositing tasks have been simplified into a single system, based on the RASSOR 2.0 drum. The drum acts both as an excavation device, and storage location until the rover is ready to deposit into the collection bin. The drum is articulated with two extendable arms that spring out to increase the range of motion.

Movement

The rover's mobility system is based on the Rocker-Bogie platform. Passive suspension, built with carbon fiber, and a geared differential allow the rover to maintain contact with the ground in practically any situation. Airless tires, or Tweels, 3D printed out of TPU are mounted to a drive motor that pivots on a vertical axis with stepper motors for steering on the four corner wheels of the robot. The remaining two wheels sit as idlers for increased weight distribution. Driving motors were upgraded to significantly reduce weight and power consumption.

Electrical & Computer Systems

Electrical Distribution

Utah Student Robotics decided upon using two, 6S Lithium Polymer batteries to supply 24V to the electrical components. The battery voltage is converted to two additional voltages, 14V and 5V, to support the various components. Two custom PCB's were designed to improve diagnostics and connection reliability and decrease system footprint. The full system is expected to consume approximately 220Wh during a 15-minute competition round.

Autonomy Software With Convolutional Neural Network

The robot utilizes an Nvidia Xavier with several microcontrollers running the Robot Operating System 2 (ROS2). Our system was designed to rely on two Intel RealSense cameras to perform simultaneous localization and mapping for autonomous navigation.

To autonomously mine and dump, The robot relies on preset routines ending when our contact mic estimates enough gravel is collected. Together with a state machine switching between navigation and mining, the robot can successfully execute 'laps' of the competition cycle.