Lunar Mining: Designing a Robust 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 simulated Lunar terrain. The competition goal is to utilize automation and sensing alongside mechanical systems to harvest icy regolith (gravel) from beneath the satellite's surface.

This year, Utah Student Robotics sought to improve upon the design from last year. The 2019-2020 rover is based on proven NASA concepts, such as the RASSOR 2.0 digging drum, and the Rocker-Bogie mobility platform.

Design Strategies

Our goal was to design a robot that is lightweight and fully autonomous. To ensure these goals were met, we performed 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 forces and torques on our digging drum and wheels so we could design the scoop size and grouser dimensions as well as size our motors correctly.

Drum Design

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

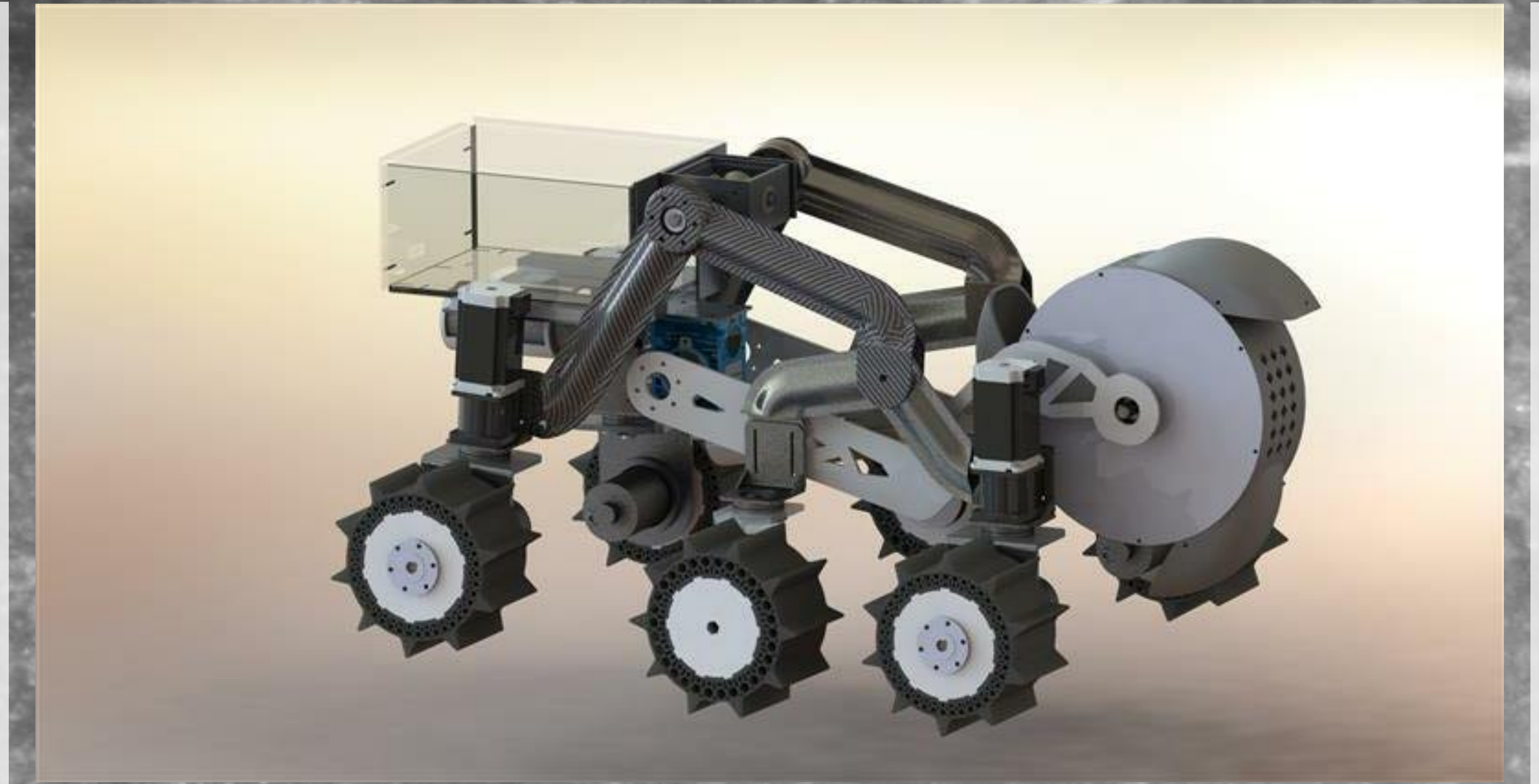

Fig. 1 Full render of our robot.

Methods

Research/Trade Studies

We examined our own previous designs, robots from other schools, and solutions from NASA. We examined all of the design options we had using a weighted decision matrices where each option for each subsystem was evaluated according to cost, weight, simplicity, and other qualitative 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 before moving on to the next phase. Each part designed was reviewed and approved by another team member to ensure functionality and manufacturability.

Simulation and Testing

Before full scale models were constructed, prototypes were 3d printed or assembled out of cheaper components first. A mini pit and drum tester were built to test the digging assembly while the mobility platform was assembled.

Result

While the Utah Student Robotics team was cut short of completing construction of the robot by the COVID-19 pandemic, all subteams were able to collaborate to design and begin a construction on an autonomous mining robot that excels beyond all previous designs.

Mechanical

Digging and Material Collection

The mining, collection, 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 on two curved arms by using a motor and worm gear combination.

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, printed out of high quality 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.

Electrical & Computer Systems

Electrical Distribution

Utah Student Robotics decided upon using 2, 6S Lithium Polymer batteries to supply 24 volts to the electrical components

Autonomy Software With Convolutional Neural Network

The robot utilizes an Nvidia Jetson TX2 running the Robot Operating System (ROS). Our system was designed to rely on two Intel RealSense cameras to perform simultaneous localization and mapping.

To autonomously mine, the robot relies on two machine learning models that get input from a contact microphone on the digging arm. A convolutional neural network (CNN) is used as the digging occurs to determine what material is currently being mined. The second model, a CNN followed by a bidirectional long short-term memory (LSTM) recurrent neural network (RNN), analyzes a recording of the drum freely spinning after mining to estimate how much target material has been mined.