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Kinematic Analysis of a Robotic Arm for Remote Control Applications

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Abstract

The University at Buffalo Space Bulls team has designed a prototype planetary rover to compete at NASA's Johnson Space Center as part of the 2015 RASC-AL Exploration Robo-Ops Competition. In order to provide the necessary remote manipulation capabilities to collect rock samples, a 2 segment arm with 4 degrees of freedom, and an end effector was designed. The arm is driven by linear actuators from Frigelli in order to provide the necessary torque and take full advantage of lever arms. In addition the actuators are lightweight and provide more power, precision, and range of motion than servo motors. 3D printed parts allowed for rapid prototyping before precise laser cut parts were fabricated. This combination of build speed and precision allowed for rapid testing, modification and final integration of the arm with the University at Buffalo Space Bulls team's prototype rover and control systems.

Design Requirements

In order for the robot to be successful, the robotic arm must be able to maneuver around unwanted rocks and obstacles to pick up the desired rock samples.

- The arm must reach at least 22 inches.
  - Reach out to the terrain in front of the rover to acquire rock samples
  - Stow within the perimeter of the rover
  - Reach storage bin to drop sample in

The weight of the rock payload and manipulator determine the loading that the arm linear actuators must support. The geometric configuration of the linear actuators on the arm will determine the reach and lifting strength of the arm.

The manipulator design must be based on the samples that needed to be handled.

- Irregularly shaped rock samples
- Diameter from 2 to 8 centimeters
- 20 to 150 grams
- Pick up off variety of surfaces (large rocks, gravel or sand)

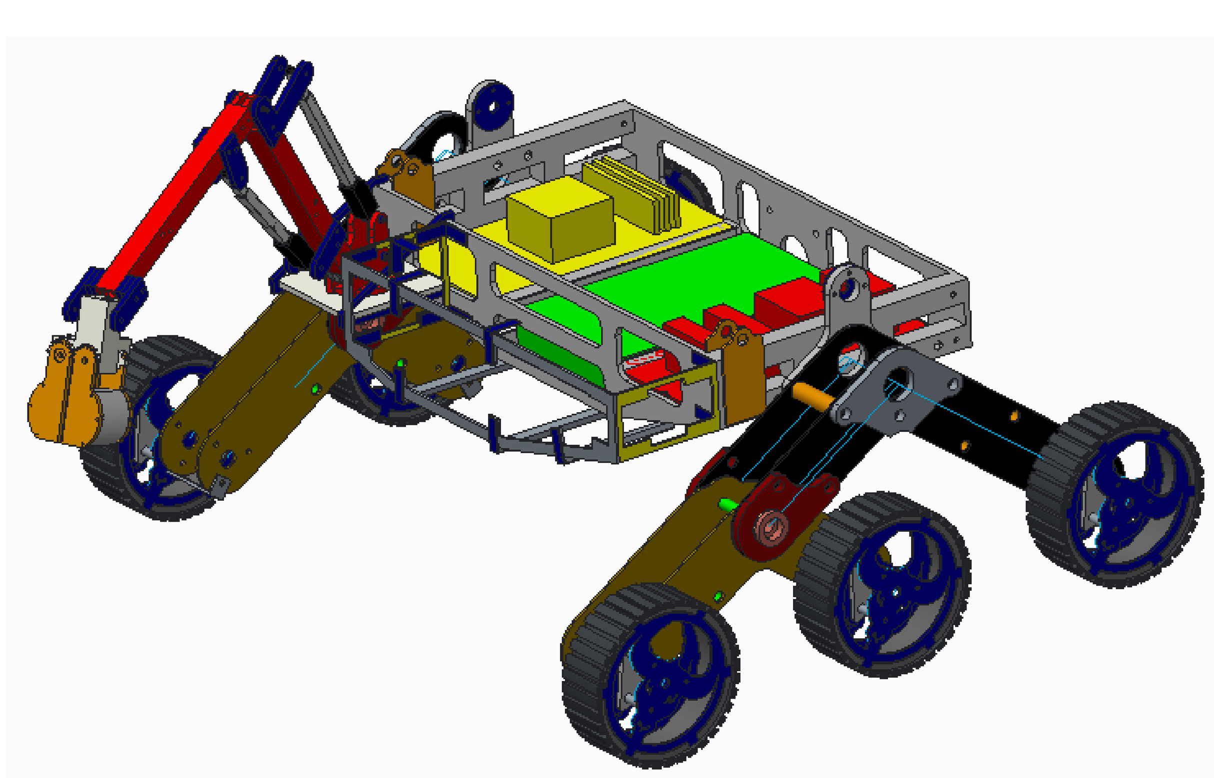

Figure 1 – CAD Design of Rover

Conceptual Model

Using Creo Parametric 2.0 we developed a model of the arm on the rover. This model was then used to ensure that we had designed an arm that would fit on the rover and stow properly while the rover travels and before deployment. Using Creo's finite element analysis and ANSYS, the arm was run through a simulation with the amount of weight that it would see during competition. This data was then used to make a decision on which motors to buy, and the required material type and thickness.

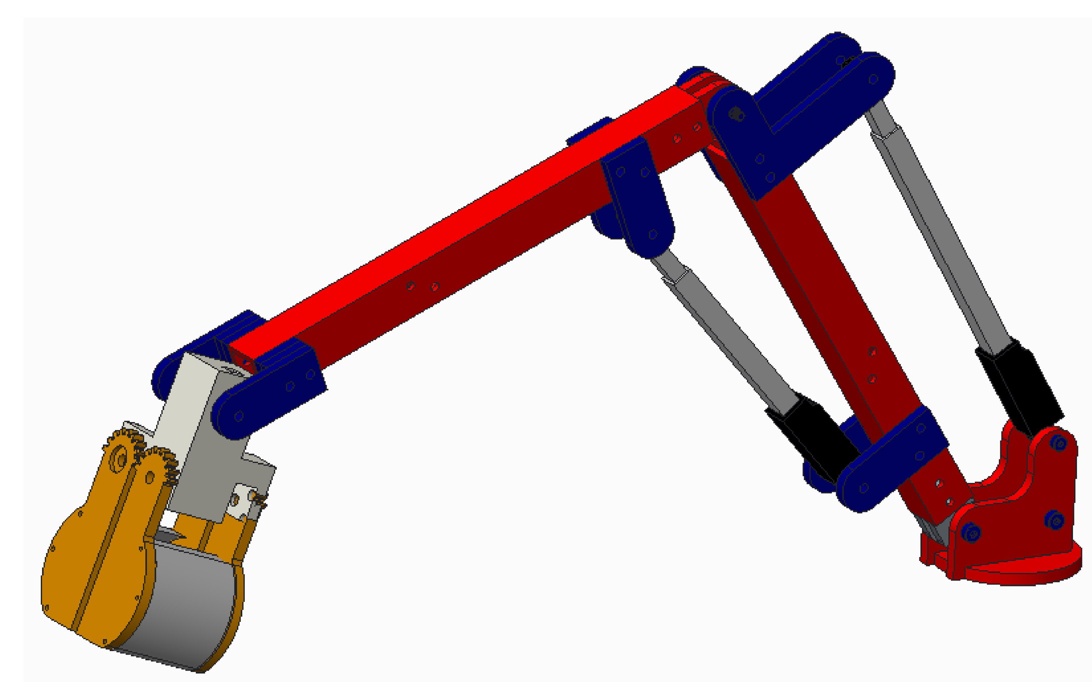

Figure 2 – Conceptual Model

Development

The ANSYS data that was obtained was used to determine the required thickness of the arm parts as well as the amount of torque required to raise the arm from full extension. Using ANSYS we were able to recreate the arm several times, testing its movement, to see if it would be suitable for rock collection. This allowed us to test the arm with out having to build it, saving time and resources.

3D printing was utilized to rapidly prototype parts and build a full prototype arm. Physically examining this prototype gave a better sense of the arm's ability and reach while placed on the rover. After fine tuning the geometry of the linear actuators and linkages to fit the rover, sturdy aluminum parts were laser cut. The prototyping process and precision of laser cutting allowed us to assemble the fully functioning aluminum arm very quickly.

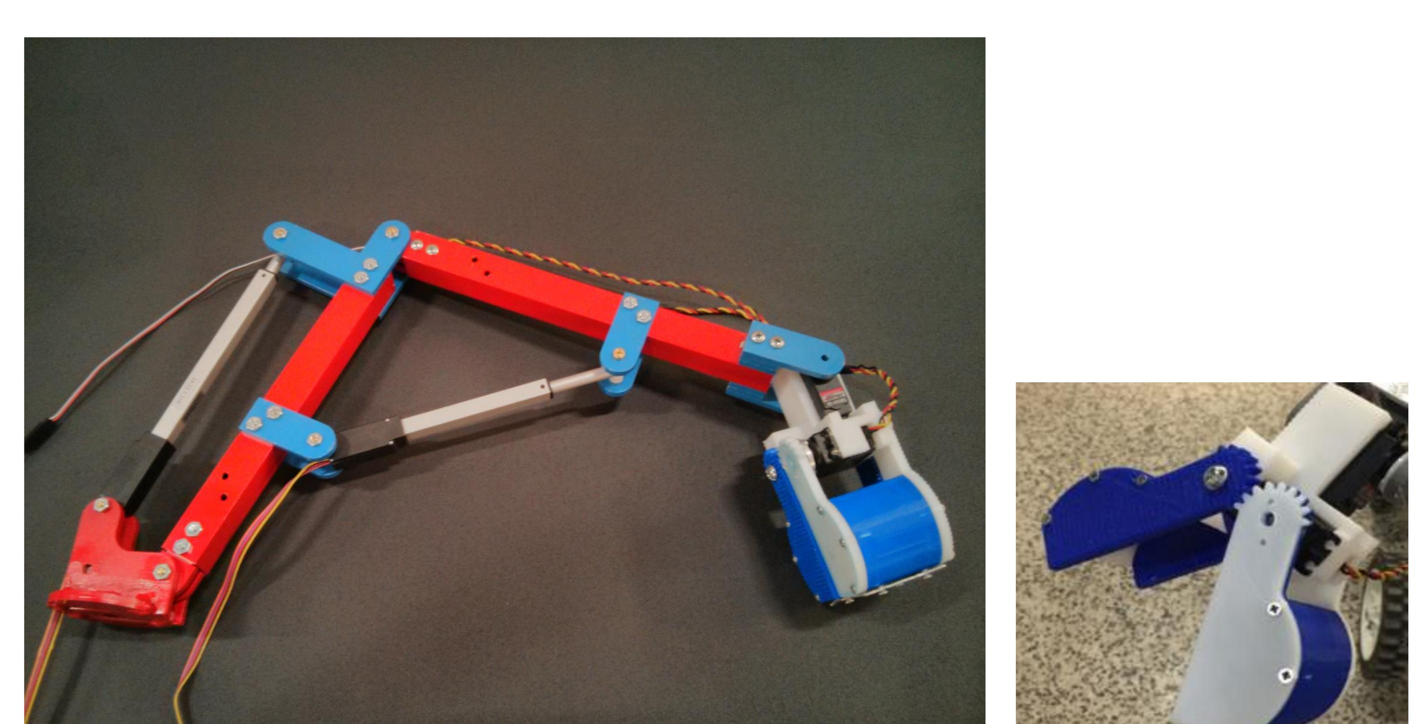

Figure 3 – Final Arm and Manipulator

Implementation

We installed the aluminum arm on to the rover and are currently in the testing phase. All parts are bolted together so that any component can be easily removed tweaked and replaced for further testing. The electrical and communications team have helped to power and create a control system for the arm. Testing is being simulated on rock samples similar to that of what will be encountered at competition.

- Arm rotated using a Hitec HS-785HB
  - 1:6 gear ratio
  - 1,098 oz-in of torque.
- Shoulder and Forearm driven by Frigelli L16-P 140 mm and 100 mm Linear Actuator respectively
  - Operate on 12V and 0.65A
- Peak lifting force of 200 N at 4 mm/s
  - 100 N at 10 mm/s
- Feedback potentiometer monitors position.
  - Accuracy of 0.5 mm
  - Communicated to computer for control

We must be able to run the rover for a minimum of one hour on a single charge. Our testing indicates that the arm draws little power and will not deplete our battery. The measured lifting force for all positons is more than sufficient to pick up several samples at a time.

Conclusions and Moving Forward

Work will begin testing the arm's true durability and reliability overtime in varying stress conditions. This arm will be integrated with the camera monitoring system to aid in rock sample identification and retrieval. The arm will be programed with set home positions so the operator does not have to continuously move the arm to common set positions.

The arm was tested to pick up objects the size of a tennis ball and was successful in doing so. We were able to fulfill all of our requirements. The arm is very lightweight, swift and maneuverable. It is remotely controllable and has a very long reach. It employs a very simple design, uses minimal materials and electrical power. The rover will be completed to participate in competition at the rock field NASA uses to test their planetary rovers at the Johnson Space Center in early June 2015.

Acknowledgments

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