NASA Space Grant Robotics Challenge

Colorado State University

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Our team's primary objective was to design and build a robot, which would autonomously navigate through a simulated extraterrestrial terrain, relatable to Mars, toward a radio beacon. Our robot's design was partially inspired by NASA's Curiosity Mars Rover, - from which we used the six-wheel drive in a skid-steer configuration. An original section of our design was the suspension system, which allows the robot to move through rough terrain with ease, because of the independent functionality taken on by each wheel. This robot is controlled by an Arduino Uno microcontroller and navigates obstacles using an array of infrared sensors, ultrasonic sensors, a compass module, and a radio transceiver. The chassis relies on 3D printed parts to optimize strength, while keeping the components at a low weight. With these different utilizations of design and technologies our NASA Space Grant rover was born.

Design Process

Prior to our first group meeting, our team had set up a Google Docs page where all team members could provide input as to the design of our robot. This page allowed us to brainstorm different ideas for how our robot was going to be powered, how it was going to move (wheels, tank-like tread, etc.), what the chassis was going to be made of, and what microcontroller we were going to use. Once this was completed we discussed as a team the pros and cons of each design option and how each would affect total cost and time to produce. Through this process we came up with our finalized product and what we had pictured it looking like. This came out to be a 6X6 skid-steering rover that utilized Arduino Uno and Arduino Mega microcontrollers, two ultrasonic sensors, and a chassis comprised of 3D printed parts.

Mechanical:

Our chassis is comprised of thirty one 3D printed parts, each of which was modeled first using the CAD software Creo Parametric 2.0. After converting each part into separate STL files we were able to specify printer speed, temperature, and filament thickness when 3D printing. Each part was printed using ABS plastic, and designed specifically to fit with non-printed purchased parts. We chose ABS plastic because it is lightweight, durable, and allowed us to integrate our own designs and size specifications. The center motor compartment (See Figure 1) is different from the two outer ones because it allows the center wheels to sit lower which gives stability and prevents the vehicle from high-centering.

Figure 1: 3D Printed Bottom Chassis

Connected to the bottom of the chassis (creating the top of the robot) is a sheet of ABS plastic that holds the microcontrollers and other electrical components (See Figures 2 & 3).

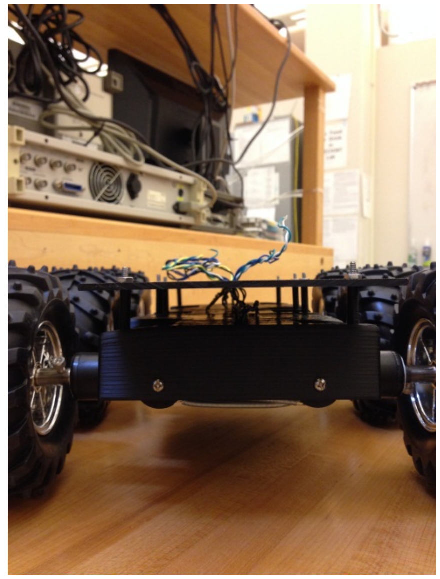

Figure 2: Chassis with ABS Plastic Sheet

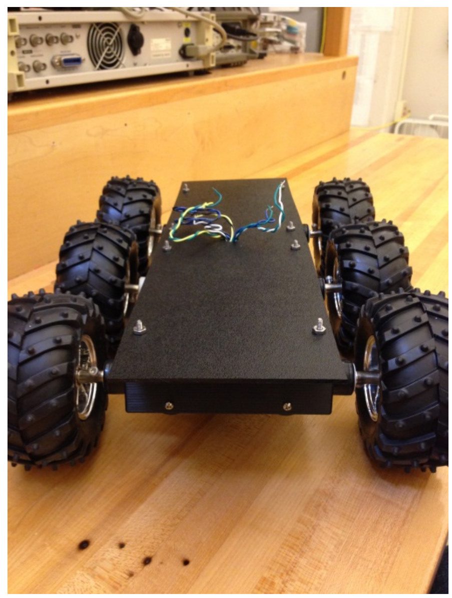

Figure 3: Front View

Once we started manufacturing pieces for the chassis, one challenge we ran into was what we were going to use for the suspension. We brainstormed a few ideas and what we landed on involved springs and Velcro straps. Having springs on one side and a Velcro strap on the other (see Figure 4) allowed the wheels to naturally rest at a proper position while also being able to endure impact, flexing upward.

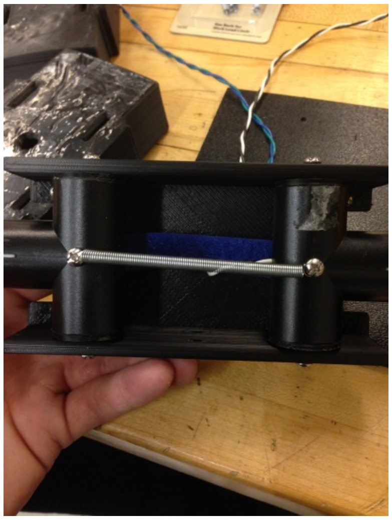

Figure 4: Original Suspension

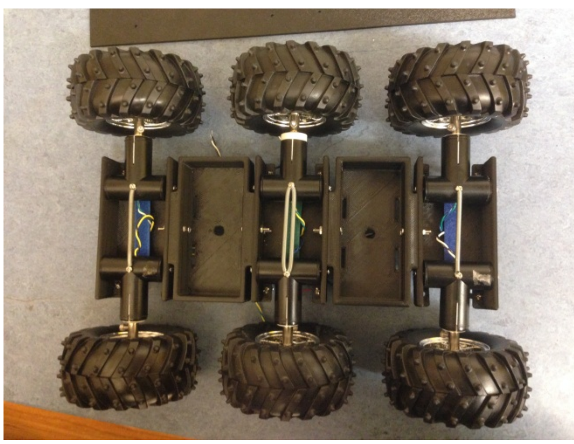

Figure 5: Original Suspension with Integrated 3D Printed Parts

At first we tested only one spring, but that proved to be insufficient as the spring was not strong enough to support both wheels. After brainstorming possible solutions we decided to add three more springs and another strap to the top. This change still allowed each wheel to flex upward, but halting it after a certain angle (See Figure 6).

Figure 6: Improved Suspension (notice cable tie straps above and below T-shaped parts)

After chassis assembly, revision to suspension, and the mounting of electrical components on top of the vehicle, we realized all of our electronics would be exposed to the elements (see Figure 7). To protect these pieces from sand, we super-glued Tupperware

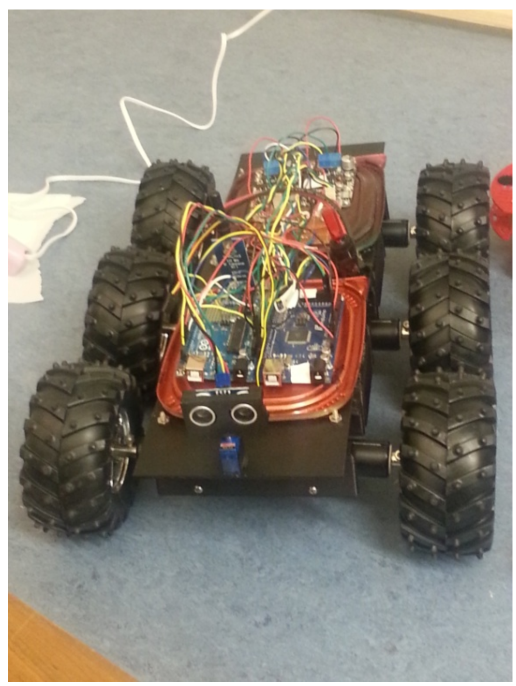

Figure 7: Featuring Exposed Electrical Parts

containers to our top sheet of ABS plastic. We poked necessary holes in the top container for the transceiver and collection of wires. By mounting our electronics to Tupperware lids we were able to attach and detach the container portion to the lids thus enclosing our electronics and protecting them from any possible debris(see Figure 8).

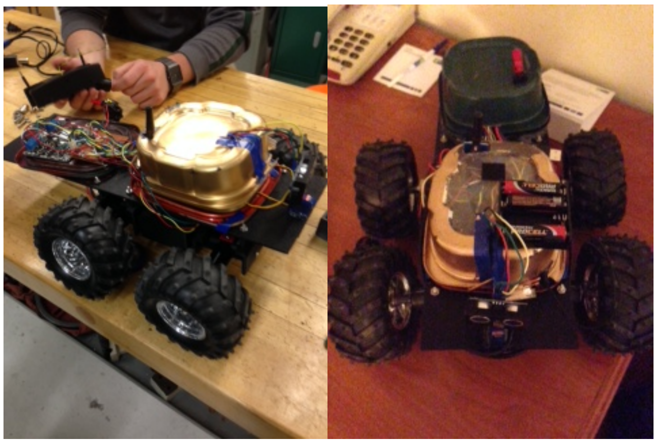

Figure 8: Tupperware lids for Protection

Electrical:

The electrical components of our robot consist of six motors that control the six wheels, one servo motor, two ultrasonic sensors, one compass, a transceiver, one battery pack, and an Arduino Uno and Arduino Mega microcontroller. We designed our robot so that one ultrasonic sensor would be mounted onto the servo motor on top of the robot and the other underneath the top sheet, mounted at an angle. This allowed the ultrasonic sensor on top to sweep 180° identifying any possible objects within the sweep range (see Figure 9). The second ultrasonic sensor was mounted underneath the top sheet of plastic at a 30° angle to the horizontal. This configuration allowed the ultrasonic sensor to identify any possible holes or ditches in front of the robot notifying it to stop and chose a different direction. We also fixed an on/off switch that was attached to the Tupperware that aided with testing (See Figure 10).

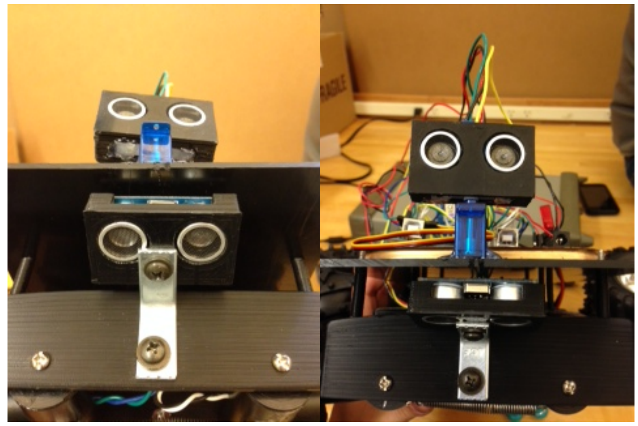

Figure 9: Ultrasonic Sensors

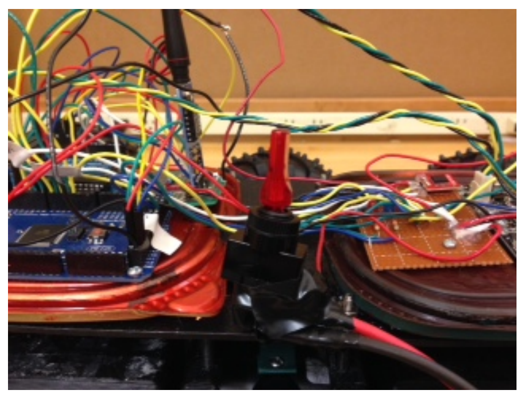

Figure 10: On/Off Switch

The purpose behind having both an Arduino Uno and Arduino Mega microcontroller was mainly to control all robot operations (see Figure 11). The primary function for the Uno was to control the transceiver because it has to monitor radio signals for several seconds at a time. The purpose of the Mega was to control all other electrical components of the robot such as motors and sensors.

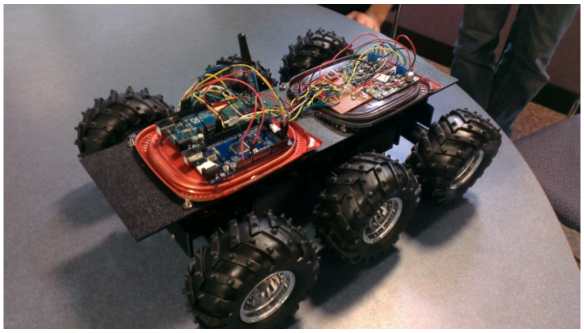

Figure 11 Arduino Uno and Mega on Left Side of Figure

Programming:

The first step was to use Arduino coding to enable the robot to head west. Separate strings of code were also developed for the transceiver and sensors. By using the Arduino integrated development environment (IDE) we developed code that allowed our robot to drive forward, head west, avoid obstacles, and navigate towards a test beacon. The most significant challenge in the programming was the obstacle avoidance with the sweeping ultrasonic.

Testing:

Our very first test was of all six motors and our initial choice for our battery pack. Overheating of the motors occurred during this test requiring us to adjust our power source voltage. After assembly, and the connection of all circuitry, our robot was tested on its ability to head west. We then tested this ability on table tops and on the floor, the rotation of both wheels opposing each other as it completed a tight circle. Our suspension design held firmly as our robot glided across small obstacles with ease. Both sensors worked well, and we adapted the sensing range as necessary as the sensor sweeped left to right.

Setbacks and Lessons Learned:

About a week before the competition we realized the front and back set of wheels opposing each other were fighting to rotate our robot. The unanticipated effects of a non-circular tire pattern on skid steering dynamics contributed significantly to the rotation problems. We considered removing the back set of wheels so our robot could complete tight circles. A few days before the competition, one of our motors had stripped a secondary gear, thus crippling one of our wheels. At this point we had no choice but to limit our six wheel drive robot to four wheels. Considering the manufacturer's advertised data on torque limits and the reasonable amount of tests we performed, the motors should not have failed us in this way. As the three day countdown to the competition began, our motors weakened which affected our robot's performance at the sand dunes. Sizable rocks became an issue due to the lack of estimated power from all six wheels.

Due to limited testing we performed with the Beacon, our robot struggled to maneuver towards the Beacon provided at the dunes. We had to adjust our head west programming, although our move forward coding worked fine. At times we experimented with a sweeping function where our robot traveled in a wide arc. At the sand dune competition we experimented with different programming styles. Although we did not quite obtain a fully functioning program, we persistently improved the program throughout the challenge.

As with any robotics competition, it is always important to complete testing as early and frequently as possible. If we would have done so, the issue with the turning dynamics might have caught our attention earlier on. Debugging is an important process that we unfortunately ran out of time to do properly. However disappointing these setbacks may seem, we all have learned important lessons and enjoyed our time at the Great Sand Dunes National Park.