Wild Tupper 2 Rover

Team: Talk Nerdy to Me

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1. Abstract

The objective of this competition was to design and build a rover that is able to autonomously navigate through a simulated Martian environment. Improvements were made to the design and mechanical features of a team member's previous space grant rover, which was an attempt to reverse engineer an existing all-terrain robot chassis.

The chassis features a six wheel design with independent twist suspension on each set of wheels. With the application of IR sensors, a more dynamic suspension system, and an investment in higher quality motors, our robot was much more successful at the 2015 Space Grant Robotics Challenge than we had originally anticipated.

2. Introduction

The purpose of NASA's Space Robotics Challenge was to increase the level of understanding of simulated robotic exploration on a Martian-like environment. The Great Sand Dunes National Park in Alamosa, Colorado provides comparable terrain to a Martian surface. Known existing hazards on a Martian surface that the sand dunes simulate include sand, rocks of varying sizes, and wavering slope terrain.

Our design was inspired by a team member's 2014 NASA Space Grant robot, which was based on a preexisting, six-wheel, all-terrain robot. After analyzing the faults in last year's design, the team made revisions and proposed a more durable and adaptable robot. The primary differences in the designs were the motors and the types of sensors

3. Design Process

Initially, it was decided to improve upon a team member's previous design. The design process was focused on the enhancement of the already existing design, rather than creating an entirely new one. The previously existing robot was a six-wheel, all-terrain rover with independent wheel suspensions. A few of the problems the original robot experienced were insufficient spring strength in the suspension, stripping of the motors, and an overly-complicated sensor system.

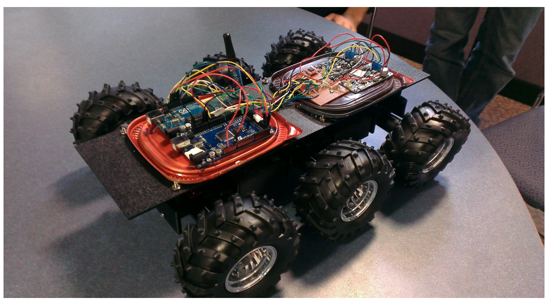

Figure 1: The Original Wild Tupper

Using that knowledge, our team moved forward in the design process. After much deliberation, it was decided to improve the design of the original Wild Tupper in the following ways:

- Improving the suspension design to provide stiffer suspension
- Redesigning the motor housings to fit the new and larger motors
- Altering and reprinting the design of the chassis
- Using an entirely new electrical and sensor system

From this list, we were able to finalize our design and move into the research phase in order to improve and advance the Wild Tupper 2 in all aspects.

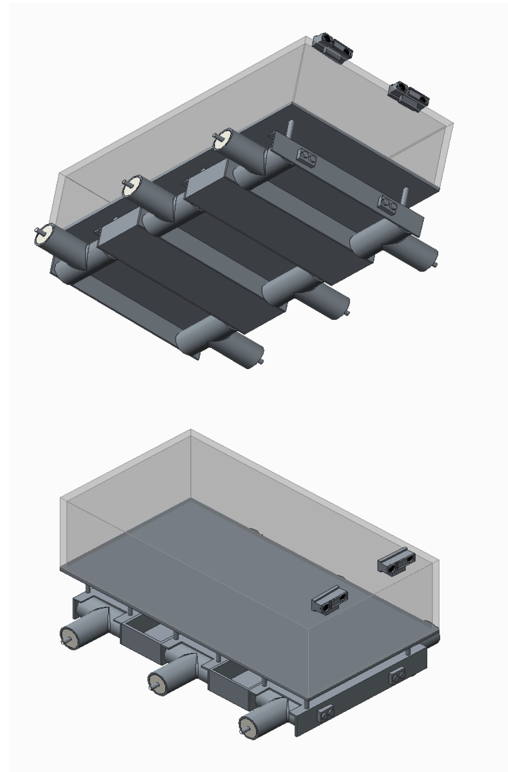

Figure 2: Original Design Concept for Wild Tupper 2

Overall, we decided to improve upon the Wild Tupper 1 for many reasons. Being a six wheeled robot, the Wild Tupper 1 experienced much success overall. The independent suspension tested in the previous robot proved to be a strong design that was able to crawl over rock, gravel, and sand with relative ease. Another reason we chose to keep the original design was due to the simplicity of being able to test with an R.C. kit and wire the motors electronically. We were able to begin the testing phase much earlier due to the ease of the design.

One of the most unique aspects of the Wild Tupper 2 is the suspension. Our suspension was designed in order to achieve the best obstacle clearance, as well as obtaining the best agility when en route on a course while keeping all wheels on the ground to supply maximum traction. We tested several torsion spring sizes and gauges ordered from Grainger in order to determine the best fit. The springs we chose were 13 gauge springs with 16 ft lbs of torque. The suspension design allowed the wheels to move independently of each other, which granted agility throughout the sand terrain.

Previously using sonar sensors for the Wild Tupper 1, they were inconsistent and inaccurate with the given terrain. Keeping true to improvements, it was originally decided to use IR sensors as a primary, and touch sensors as a secondary sensor. Electrically, it was powered by six Pololu 34:1 Gear motors and the selected IR sensors were used for navigation and obstacle detection. Later in the testing phase, however, we decided to no longer implement the touch sensors into our design, as the design was sufficient enough in obstacle clearance.

In finalizing the design, much of the engineering analysis was completed in order to ensure high quality performance. Research was conducted in order to determine numerical values for the IR sensors implemented and specifications for the DC motors were established. Finally, CAD models were created in Creo Parametric of the chassis and motor housings in order to 3D print them.

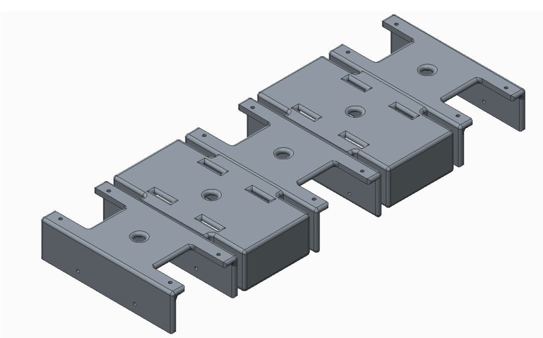

Figure 3: CAD Design for Robot Undercarriage

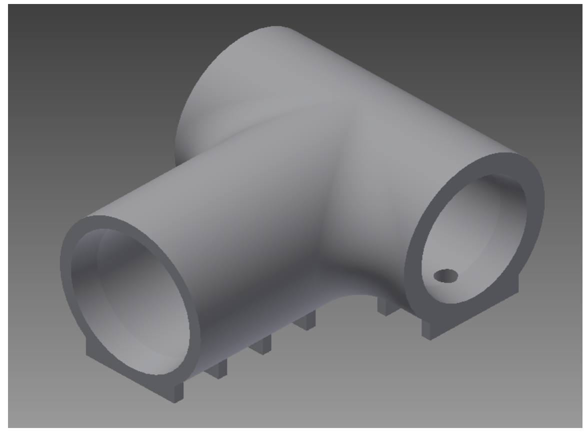

Figure 4: CAD Design for Motor Housings

4. Fabrication and Assembly

The chassis, suspension and motor housings were produced using a 3-D printer and were made of ABS plastic. Although this is a rapid prototyping method for fabrication of designed parts, our team spent over 35 hours printing all 21 parts and the many spare parts needed during prototyping. While the motor housings were originally going to be machined out of PVC pipe T-elbows, they proved too difficult to machine.

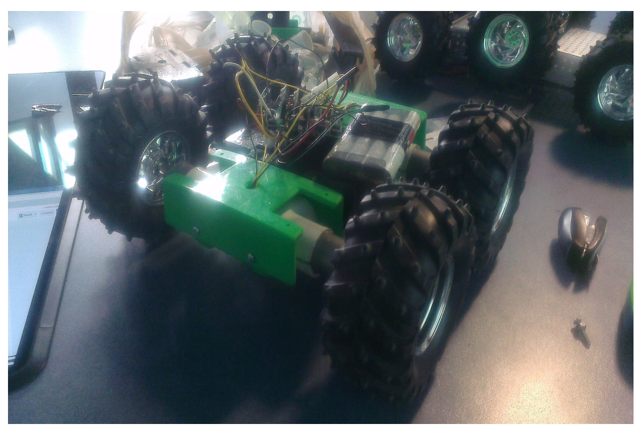

Figure 5: Wild Tupper 2 Suspension Prototype

We were able to make enough for a proof of concept prototype, but decided that for the final design we would 3-D print them. After 3 prototypes and redesigns to increase their strength and durability, we printed a full set of the final design.

Figure 6: Final Wild Tupper 2 Chassis and Wheels

The top panel used for mounting electronics was made from a single sheet of ABS plastic, heated and bent to create front and back faces for mounting sensors. The IR sensors were mounted using pieces of Basswood, and hot glue and super glue as adhesives to the front panel of the chassis. Basswood was selected due to its ability to be rigid, while using hot glue as an adhesive provided a semi-permanent yet secure mount to the fixture which could be reinforced with super glue for more permanence once the placement of the pieces was optimized.

Other fasteners and adhesives used in the final design included zip ties and various forms of tape. Throughout the testing/prototyping phase, materials such as Popsicle sticks and clothespins were used.

5. Electronics and Programming

With our robots' robust design and speed, we had to incorporate electrical devices that would help navigate through sand and obstacles quickly and efficiently. Our robots control system can be broken up into three parts: Sensors Implementation, Autonomous Navigation and Integration. For our Sensors, we analyzed that our robots design would enable us to climb over most obstacles up to about 4 inches. To handle the situations where there would an object too large to crawl over we would use Infrared Sensors to detect the object. The robot would them reverse and turn either right or left depending on which sensor was tripped; left if the right sensor was tripped, and right if the left sensor was tripped.

The next part, Autonomous Navigation, was our most difficult challenge. Our first component was the Beacon receiver that would be mounted on the front of our robot. We use the recommend receiver along with an Audrino-Uno that would constantly be looking for a signal sent out by the beacon. Code was put on to the Audrino-Uno that would filter out the noisy signals before sending the real value to our main control unit. Our main control unit was another Audrino-Uno that was wired to a standard breadboard to receive and oversee our IR-Sensors, H-Bridge Motor Controllers and our Receiver. Through these components, we designed an algorithm that would drive our robot towards the beacon and strategically move around obstacles. Our robot constantly looks for a vector value from the beacon (checking first to see if it is a valid vector) and compares the current value to the previous value. This allows us to figure out whether we need to adjust clockwise or counter clockwise. The robot constantly adjusts itself to line up straight with the beacon. If the robot runs into obstacles that it can't move around then it activates a programmed method to back up and go around the object. The final part of our control system was integration. We had spent a lot of time fine tuning the code by adjusting motor speeds, sensor sensitivity and updating the system as often as possible. Overall, our robot was quick to the beacon and avoided many almost all the obstacles thrown in its' way.

6. Challenges and Lessons Learned

Throughout the design and testing processes, several challenges occurred that the team had to overcome. Initially, the design of the touch sensor mounts proved to be too rigid and too low to the ground, which caused breakage during testing. In order to compensate for the loss of the touch sensors, more time and attention was devoted to the mounting and programming of the IR sensors.

Another issue that was identified was that by using a battery for each side of the robot the power being supplied to the motors was often uneven. This was caused by having two separate voltage sources for each side of the robot, which caused it to turn to one side. We compensated for this by altering the output values in the code to keep the wheel speeds even enough to allow the robot to travel in the direction that the beacon receiver was telling it to go.

One problem that plagued us during the electronic development phase was circuit failure. Two compasses, 2 touch sensors, one IR sensor, and a transceiver either fried or stopped working for unknown reasons. This caused us to change the programing and sensors a lot in the final weeks before the competition. This caused us to forego touch sensors and a compass completely which also meant changing the code to compensate for the lack of sensory input.

During the competition, the courses illustrated the robot's strengths and weaknesses. The Wild Tupper 2 was successful in traversing the sand terrain and managed to find the beacon several times. However, a few of the obstacles proved to be challenging for our robot. For example, the robot's IR sensors were incapable of detecting the deep sand craters, so it was unable to avoid veering into the hidden obstacles. Potentially due to previous damage from previous runs, the Wild Tupper 2 also struggled in detecting the wooden boards positioned on the sand courses. Finally, the robot experienced difficulties when presented with steep inclines, mainly due to insufficient power supply after it had been running for almost 4 hours. For future robotic improvements, we would improve the programming by incorporating scenario code for the IR sensors for when the robots approach steep hills, and we would also be prepared with a larger supply of backup batteries.

7. Conclusion

The Wild Tupper 2 excelled in all areas at the 2015 Space Grant Robotics Challenge and was considered a huge success over the original Wild Tupper and in our attempt to reverse engineer an existing all-terrain rover. We successfully achieved all of our previously set goals, and the Wild Tupper 2 received the award for "Best Demonstration of Beacon Navigation" for being the first robot to have a functioning navigation system the night before the challenge and successfully navigating the sandy terrain and reaching the beacon consistently on the day of the challenge.

Figure 7: Final Wild Tupper 2 on Competition Day