Ram Rover: Autonomous Vehicle

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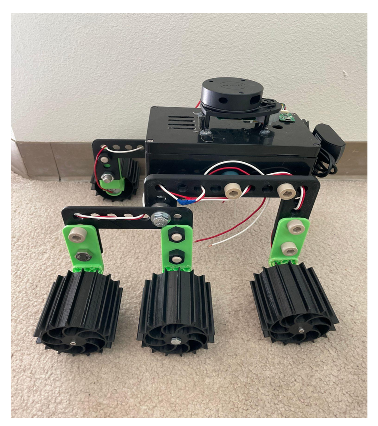
Abstract

The Ram Rover is a autonomous rover like vehicle that is designed to map and navigate various types of environments. It achieves this through a number of technological and mechanical ways.

The main body design of the rover is based around NASA's Rocker-Bogie wheel and leg design which utilizes two front fixed legs attached to the main body with two smaller free rotating legs at the back of the front legs. This with six individual motor housings and wheels serves as a versatile and adaptable combination.

Electronically the Rover is governed primarily by a Raspberry Pi 4 serving as the "brain" of the device for data processing and trajectory. The Pi is connected to multiple components including a digital camera for environment imaging and providing visual odometry, a 360° LiDaR for path finding and logic and an Arduino Uno connected to a motor driver to control the motors in the wheels.

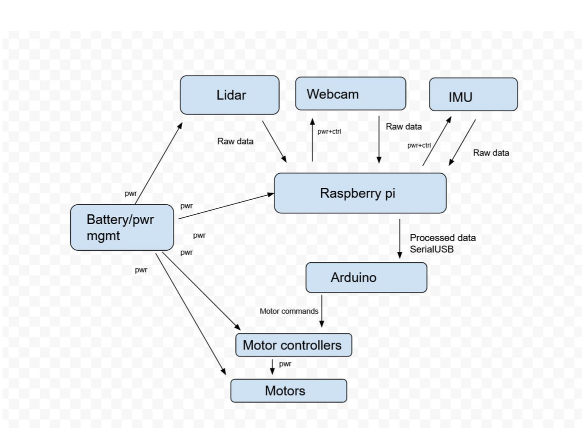


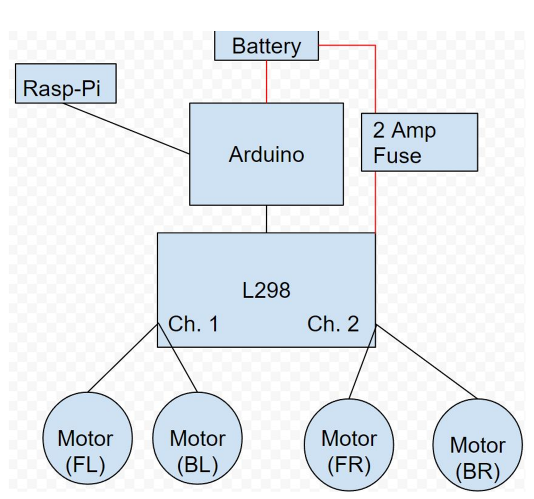
Introduction

The Ram Rover, sponsored and advised by CSU Space Grant Program is a Mars-like rover, which competed in the 2023 COSGC Colorado Robotics Challenge against other rover-like vehicles from schools across Colorado. The challenge was specifically designed to see the limitations of each vehicle, testing their capabilities across multiple courses that were designed to simulate various environments and obstacles.

To ensure the Ram Rover was ready for the challenge, the team split into two groups: a design team and a systems team. The design team started by developing an initial concept for the rover, iterating the design until they arrived at the final Ram Rover. Meanwhile, the systems team chose the desired processor and utilized an online testing environment to test the software and sensor iteration, ensuring that the rover was fully operational and prepared for the challenge.

While designing the physical rover, the team encountered several primary challenges. Keeping the weight of the rover within the specified limit was one of the major challenges. Additionally, the team had to find a way to prevent the wheels from slipping on the motors, which proved to be a formidable obstacle. On the software side, the biggest challenge was integrating the camera and LiDaR on the real-world robot. These challenges were difficult to overcome, but the team persevered and produced a final product that they were proud of.



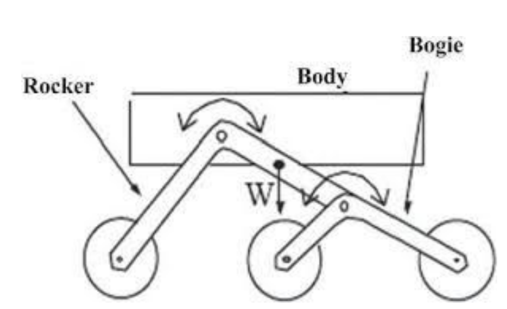


Materials

- Raspberry Pi 4 (4 Gb)
- 360 Degree Lidar
- Arduino Uno
- Adafruit 9-DOF Orientation IMU Fusion Breakout
- ABS Plastic Project Box
- Web Camera
- USB Power Bank
- 4 PACK L298N Motor Drive Controller
- Ball Bearings (x2)
- 1/2"-13 Nylon Bolts (x14)
- 1/2"-13 Nylon Nuts (x14)
- ½"-20 Steel bolts (x4)
- ½"-20 Steel Nuts (x4)
- PLA - Black and Green
  - Large Legs (x2)
  - Small Legs (x2)
  - Motor Housings (x6)
  - Wheels (x6)

Methodology

For developing the body of the device supplemental parts were created and assembled in Solidworks to get a general idea of what the device would look like. Parts such as the legs, motor housings and wheels were then printed in multiple iterations using PLA to begin testing. Initially the device was extremely heavy as steel ½"-20 nuts and bolts were used to connect the body to the legs and the legs to the motor housings totaling 8 pairs which ultimately added around 2 lbs to the device. These were then replaced by lighter nylon hardware. Motor housing and wheel combinations were treated as subassemblies to the body and went through many iterations; specifically resizing the components to better fit the device was a challenge and required many assembly and practicality tests.

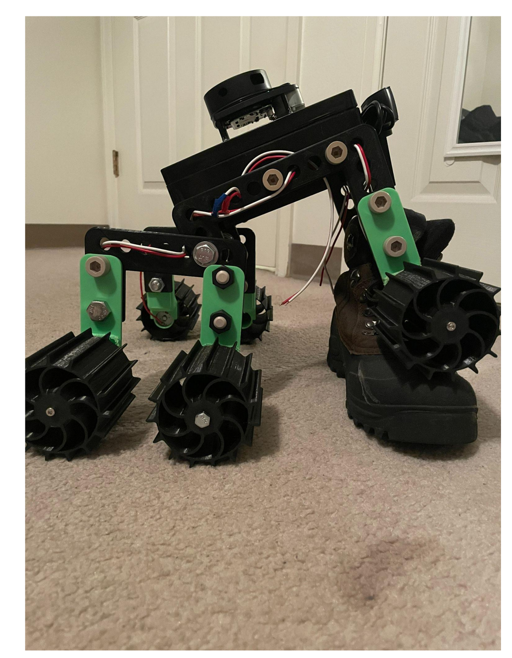


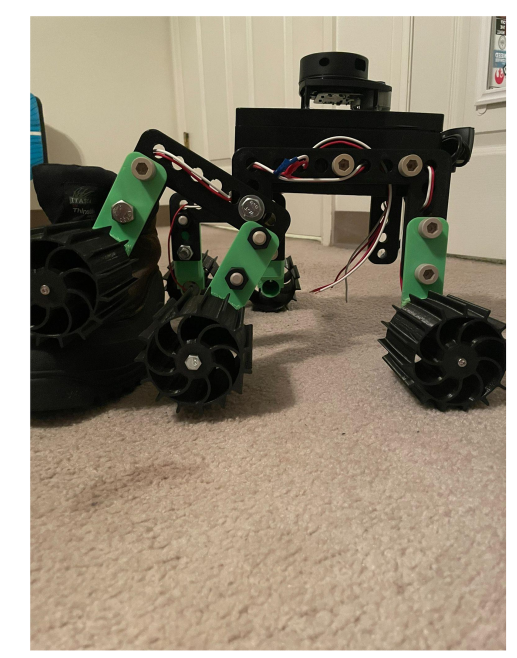
In order to develop the electrical components, the initial step was to select the ROS2 framework as the foundational software. Subsequently, an accurately scaled model of the robot was created, followed by the selection of suitable sensors. Considering the significant decline in the cost of lidar technology, a lidar sensor was chosen as the primary sensor. The sensors were integrated into a simulation to assess their performance, with the camera serving to improve front-tracking and lower angle point-tracking. Furthermore, an IMU was selected to enhance odometry data through an extended Kalman filter. Initially, motor encoders were not incorporated into the design of the robot, leading to challenges during real-world testing. As a result, the team had to improvise and employ the webcam and OpenCV to fabricate odometry, given the realization that encoders were essential for improved turning accuracy. In summary, the primary challenge encountered was the necessity for encoders, which required the team to devise alternative solutions.

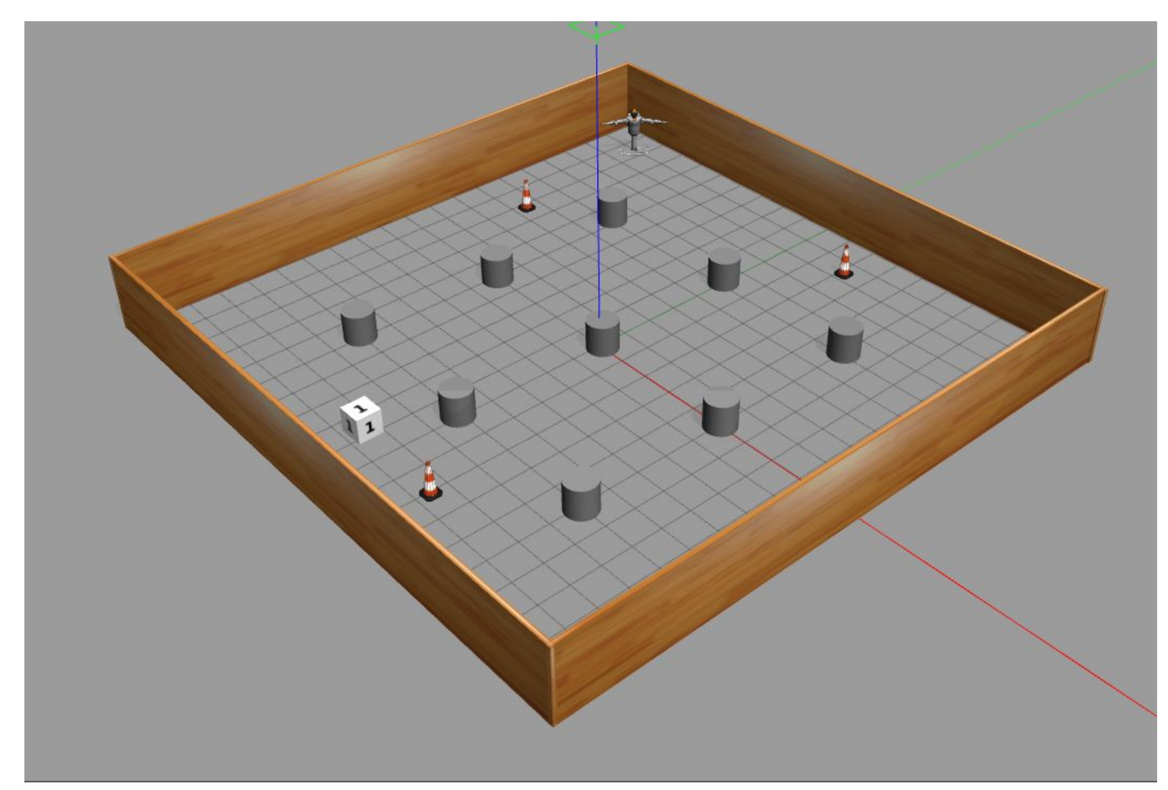
Results

Rigorous testing was performed that resulted in multiple different outcomes. From the time this is completed the competition has not yet happened so a final test has not been performed. However, adequate results have been collected so far:

- The overall weight of the device is in operating condition and below the challenge restriction of 4 kg.
- Structural components like legs, motor housings and wheels are extremely durable and are very hard to break under moderate expected loads.
- Slight miscalculations in cut holes and off-setting geometry from printed parts makes the device slightly off centered yet still drivable.
- It is able to travel across multiple types of terrains including, carpet hardwood and grass.
- Virtual testing through simulations showed adequate autonomous navigation capabilities
- Preliminary real world testing has shown adequate movement in the x-direction but a lack of accuracy for tracking rotations of the robot.
- Heating is a minor issue that has been somewhat alleviated by small vent hole in the top of the control box.





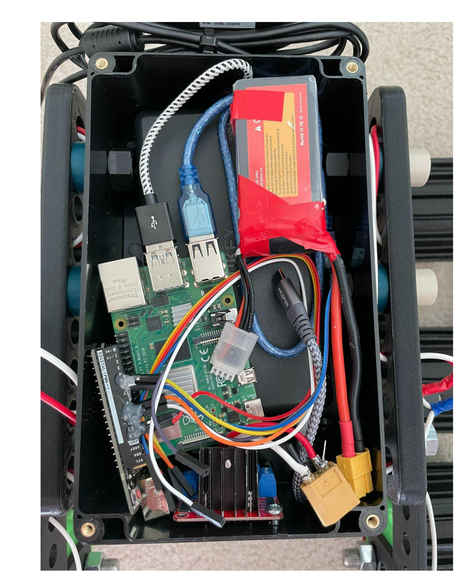


Conclusion

Although a full test of the device has not been performed the methods and results formulating the device have proven successful. The body held up extremely well with it's design and held together well through testing. The rocker-bogie design proved useful when traversing elevation changes in terrain and smaller obstacles that were not detected by the LIDaR. Small changes in the machining and extrusions in the body would have made the design more sound however, it performed the minimum tak successfully. The Electrical Components have performed well with the lidar performing better than expected. As of the creation of this poster, the camera visual odometry has not been implemented. The raspberry pi and arduino have been performing exceptionally with no errors on their parts. There are also several improvement we could do to improve the navigation. Due to a lack of funds a phone hotspot had to use used to facilitate communication between the laptop and raspberry pi. a dedicated router or travel router with greater bandwidth would improve the delay from the camera and allow for higher resolution images improving tracking. Another improvement could be a higher performance SOC such as an nvidia jetson to allow for some local processing to improve latency.

Recommendations

The main concern for future iterations would consist of using motors with encoders. This would solve the issue of the rotation not being tracked accurately. The body was put to together in such a way that it is hard to make any major modification to it without removing a significant amount of material or disassembling the device almost entirely. A larger control box would have prevented crowding of components as well making the inside cleaner and safer. Generally, everything else on the device worked as or better than expected and wouldn't require much modification minus so errors with software and poor weight distribution.



Acknowledgements

A special thanks to the Colorado State University Space Grant Program for funding and supporting this project as well as the advisors and sponsors:

- Graduate Student Jacob Gottfried, Advisor
- Dr. Yalin Azer, Head of the Space Grant Program