Project Artemis Prime:

An Exploration of Autonomous Robotics

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Introduction:

Autonomous rovers are an essential tool for exploring and obtaining geological information from planetary bodies beyond Earth and are equipped with a multitude of robotic features. This includes many mechanical, electrical, and computational components that require imaginative and logical designs to come together in a functioning machine, which is fine-tuned through continuous research, trial and error, and modification. In our exploration of autonomous robotics, we started with very little knowledge of the subject matter and the core components. Over the span of a year working on the project, we have gained a great deal of knowledge in robotic components, 3D design and printing, and applicable programming and logic. Project Artemis Prime not only taught us technical skills, it taught us we are capable of building something beyond the scopes of our imagination, through perseverance, dedication, and thinking outside the norms.

Materials and Methods:

In the beginning, we studied the functionality of SparkFun's Inventors Kit robot and learned the very basics of electronics, microcontrollers, and programming in Arduino IDE. Realizing that this little robot was not capable of traversing massive desert landscapes with many obstacles, we began to brainstorm in a new direction and worked to translate our learnings to a much different machine.

Project Artemis Prime began as a "stick and bones" rover consisting of four 313 rpm electric planetary gear motors and some RC car sand tires on a hinged aluminum chassis, where the hinge acted as suspension. We had no automation at all at the beginning, so the motors were driven by a DC power supply and a long extension cord to test the functionality of the suspension. Noticing that the suspension worked well but there was little clearance from the small radius of the tires, we designed new wheels in CAD and tried 3D printing them with FDM filament. A plastic PLA wheel and tire combo showed great improvement in navigating rough terrain, so we added a 20-volt electric drill battery and a voltage transformer to control the speed for a better range of testing. We concluded that we wanted to continue with this pivoting body suspension, so we began to design an enclosed body with a pivot function. We researched the components necessary to drive the motors like the SparkFun robot and to add automatic functionality. After 3D printing a new body and adding two dual motor H-bridge PWM motor controllers and lithium batteries for power, an Arduino uno, and a couple close range IR distance sensors, we started learning the code necessary to coordinate all the components.

Through trial and error, we were able to coordinate control of the motors through the input data of the sensors with programing in Arduino. New algorithms were continuously developed to improve the self-navigation function and obstacle avoidance, and rear sensors were added to enable a backup function, which became extremely advantageous when navigating the hallways of our engineering building. Knowing that we were going to be in a much less forgiving environment with harsher terrain, we decided to explore adding more sensors, like ultrasonic distance sensors and laser distance sensors, to provide alternatives in the event of inclement weather or conditions. After some research, we decided to upgrade the microcontroller to an Artemis ATP with qwiic connectors to enable easier connection through I2C for the added VL53L1X laser sensors and the HCSR04 ultrasonic sensors. This wiring convenience came with a new task of learning I2C communications programming, which showed to be extremely challenging for communicating with 4 of each of the VL53L1X and HCSR04. Nevertheless, we persevered and was able to program the VL53L1X sensors through an I2C multiplexer, which gave them individual addresses, but had to readdress the HCSR04 to new available hexadecimal and connect them in series. This wasn't an issue for the GYA01 IR distance sensors since they connected with a single wire each through the analog GPIO pins of the microcontroller.

We began to study printing with SLA resin printers and experiment with different types of materials. We discovered that printing with Anycubic UV Tough resin not only gave us greater precision and flexible strength for our components, but also increased printing speed for certain applications. This allowed the body design to be continuously studied and modified for improvements and to incorporate the new components, while also creating modular aspects to allow for quicker printing for modification. Various sensor locations were tested with the modular function, where only small prints needed to be swapped out, instead of the entire body. This concept was further implemented with the pivot design, where the body could be pulled apart for easier diagnosis and modification of the inner workings of the rover. Connection of the body was achieved with a threaded pivot with a slot allowing for the wires to pass through. Knowing modularity was optimal for easy removal, a custom wire connector had to be designed and printed to fit the diameter of the pass-through, while also providing a secure, removable connection; it was named a master pin connector or MPC.

When we received permission to build a large sandbox to further test the abilities of our rover, this new arena quickly exposed our strengths and weaknesses. The sandbox, which was customized with obstacles such as rocks and foam core boards, allowed us to test in an environment more like where the challenge would be held. Through testing in the sandbox, we learned the original found motors were far too fast, and the torque was inadequate for the climbs with our algorithms. These motors were replaced with 84 rpm 100:1 torque motors, almost identical in size to the previous, which solved our climb issue, but many other modifications were to come. The pivoting body design now had to be limited to avoid contorting the body, the algorithms had to be adjusted to allow for more voltage to the motors, the wheels need to be widened and printed with “tires”, and the sensors had to be moved along with adjustments to the algorithms.

Due to the long-term nature of this project, we went through many phases of optimization. We decided that having the choice of several algorithms or “modes” would be advantageous to be able to choose which sensor to use or autonomous approach to calculating the terrain. This required adding a method to be able to change this mode, which first consisted of a 10k potentiometer to create a “menu” and an RGB LED to indicate which mode it is in. Due to eventual continuous error with this method, it has evolved to adding an LCD screen and a rotary encoder switch to navigate a text menu.

To finalize the project, our aim is to create an algorithmic loop that would be able to utilize sensor readings to choose modes on its own, an “automatic mode.” A PHT sensor (pressure, humidity, temperature) and accelerometer/ gyro sensor were added to the I2C qwiic series to assist in the development of this mode. In fully autonomous mode, the rover would choose sensors and modes based on calculated weather conditions, present terrain navigation status, and rotational operation of the wheels through hall-effect sensors; This has yet to be fully implemented and is in progress at this time.

Results and Conclusions:

Through perseverance of trial and error, we have successfully created an autonomous rover that is capable of navigating Mars-like terrain. While there is much room for improvement and knowledge to be gained, we have learned through this experience, a vast amount about robotics, in mechanics and design, electrical and computational components, and functional computer programming. In addition to the robotics research, we realized the negative impact of 3D printing with resin, researched the process of detoxifying the waste material for environmentally safe disposal, and are successfully implementing it.

Visuals and References:

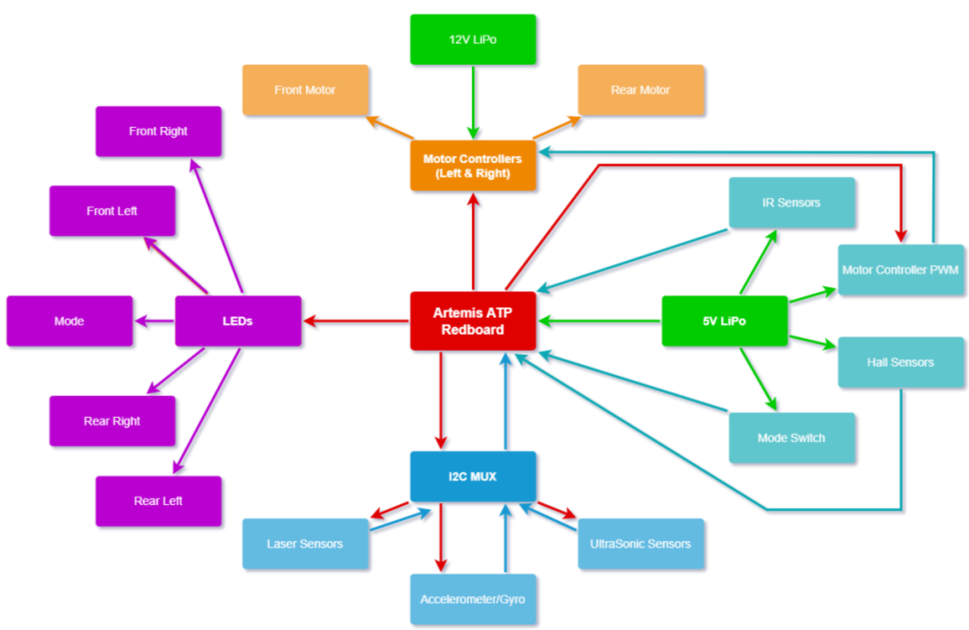

Figure 1: Microcontroller Communication Diagram

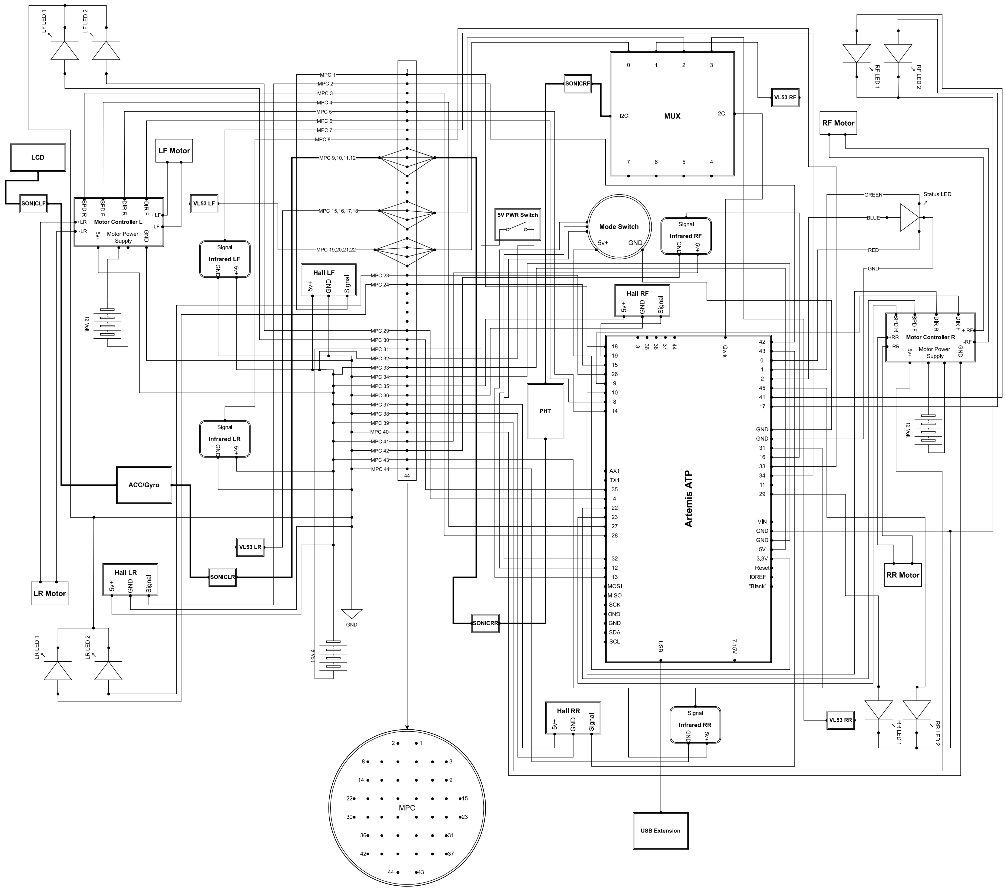

Figure 2: Wiring Diagram with MPC Connections

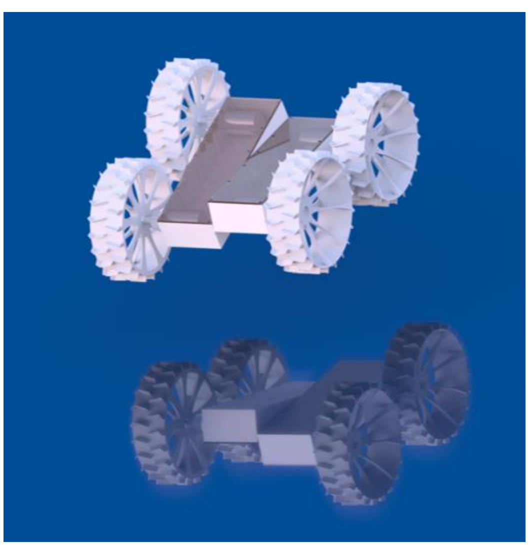

Figure 3: Original Concept

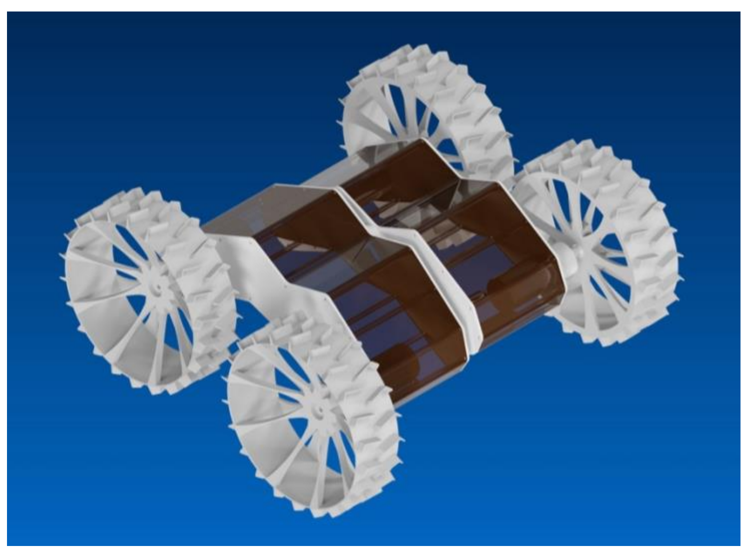

Figure 4: Final Concept

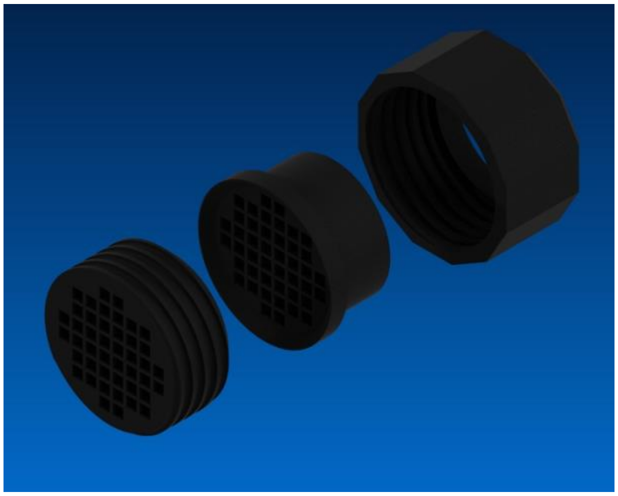

Figure 5: MPC Design

Figure 6: Center Pivot Design