Puma's In A Half-Shell Robotics Research Project: Donashello

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Abstract

The goal of this project is to gain hands-on experience as well as expand on and learn about the necessary skills and techniques for building rovers. Specifically by building and coding Donashello. Donashello is an autonomous, imitation Mars rover capable of navigating territory similar to Mars. The chassis was designed and 3D printed; the programming language is Arduino, and that communicates directly with the Arduino Due board. Months of designing, prototyping, and testing revealed different design flaws that had to be fixed and worked around and better ways to do different things needed to be developed. This has all been in order to test how Donashello will perform in a simulated Mars environment, which will happen at the Great Sand Dunes in Alamosa on April 15th through the COSGC Robotics Team. Developing the project while working with and relying on varying levels of experience allowed for a lot of growth and ideas to improve upon Donashello in each stage. Donashello is now capable of basic navigation in sandy terrain.

Donashello is an autonomous robot with the purpose of imitating a Mars rover capable of navigating territory in sandy terrain. This project aims to gain hands-on experience and expand on and learn about the necessary skills and techniques for building rovers. In order to test how Donashello will perform in a simulated Mars environment, to compete with other space grant robotics teams at the Great Sand Dunes in Alamosa on April 15th through the COSGC Robotics Team. Months of designing, prototyping, and testing revealed different design flaws that Pumas In A Half-Shell had to work around, as well as repeatedly developing better processes, including last-minute changes that had to be made.

The design process included moving through multiple prototypes. Donashello was made out of wood, plexiglass, and metal before the team settled on 3D-printing almost everything out of ABS filament: the wheels, chassis, mounts, and shell. The only things that were not 3-D printed were the legs, which are 1-inch PVC pipes, and the hardware (screws, chips, sensors, nuts, bolts, etc.). Our sensors, barring the 9-DOF, were six Sharp IR distance sensors, three on each side, that were individually calibrated and had leg mounts printed at specific angles to see any obstructions, including holes, wheel obstructions, and anything that would hit the legs. The programming language chosen was Arduino, and the chips included a BoJack motor shield, an Adafruit 9-DOF Absolute Orientation chip, and an Arduino Due processing board. Developing the project while working with and relying on varying levels of experience allowed for a lot of growth and ideas to improve upon Donashello in each stage.

The first chassis prototypes included an aluminum drive shaft and body with two motors close to the center of mass. It also included a 4x4 design to be able to go over anything, like a four-by-four vehicle. However, through testing, it was discovered that the design required more time than was needed to complete. To address this, new prototypes moved through lighter materials, like wood, and even heavier materials, like plexiglass and resin, as well as simpler designs until the team landed on our current chassis and suspension system, which uses a basic direct drive setup with four 12 Volt motors connected directly to each wheel. A shell also protects the electronics; it attaches to the base of the chassis using screws. Our entire robot was 3D printed and assembled with few modifications by the end of our first semester.

The wheels for Donashello also went through many different prototypes, all designed by Angel Padilla; she went through all kinds of filaments, first Ninjaflex and TPU, then PLA, and finally ABS. Prototypes for her designs were all very different. The first prototypes were flexible, using the Ninjaflex and TPU. The one using TPU had a mesh design, like window screening, and folded into the shape of a spherical wheel, and the Ninjaflex one had a squishy rubber-like design using more common sand treads. Next, she moved to PLA and had a design based on the Mars rover: Curiosity with spiral spokes and combination treads. The next design still used PLA but incorporated more spokes and a slightly less complex tread design, focusing on the wave treads instead of the holes and other grips. Angel's next design used ABS filament while copying the last design. The final design for Donashello's wheels was the same as the last one mentioned, except it had less spoke in order to accommodate the weight requirements.

Unfortunately, the motors wore through their housing at the last minute, and Pumas In A Half Shell had to make spur-of-the-moment adjustments, including using premade, smaller, lighter wheels. The issue was that the couplers from the direct shaft of our motors rounded out the insert for the wheels, so it was not able to engage properly. The new design coupled a shaft and a mounting bracket to wheels that were scavenged from an RC car.

The team used standard steel screws, nuts, and bolts to attach the chassis together for the hardware. Donashello also has plugs for the motor mounts that the team soldered together by hand for ease of disassembly when necessary. All of the chips, the Adafruit 9-DOF, the BoJack motor shield, and the SHARP IR sensors are soldered onto the breadboard. Donashello also has an Arduino Due processing board that controls the robot and, finally, an 11.712 Volt airsoft battery as the power source for Donashello that is wired to a switch to turn Donashello off and on.

Donashello senses the world with six SHARP IR Distance Sensors that are attached to the two front legs at three places on each leg, two sensors are near the base of the chassis to detect obstacles that will hit the entire leg, and four are next to the front wheels, two to detect holes and two to detect obstacles Donashello cannot climb over (obstacles which are approximately half the height of the wheel tall) with sensor mounts that have been printed to hold the sensors at specific angles determined by the dimensions of the robot. The sensors were also calibrated individually by hand because they have a conical laser that is coded to pretend it is a line. The code also had to have each individual calibration equation for each sensor as there was not a single one that could be calibrated the same way. This whole process was developed by Jacob Sadow, who did all of the calculations and calibrations that allowed for much more accurate distance readings and obstacle detections. Sadow also worked with Kimberly Hutchens to finalize the design of the printed mounts to ensure proper angles and security.

Initially, Donashello's program was meant to store the locations of previously encountered obstacles and use that information for navigation. However, time ran out to implement this, as the robot lacks the requisite sensors for localization. There was also an intended function for Donashello to perform tank turns, but it was discovered in the final stretch that Donashello lacked the torque necessary to perform these kinds of turns. Given more time, this issue might have been solved at the hardware level, but instead, the program was adjusted to work with less information and overcome the challenges associated with turning. Donashello is programmed to try to move forward in the direction of its original heading until its path is interrupted by an obstacle. This is determined using IR sensors on the front of the robot. Donashello tries to go around obstacles by first turning and then going forth for a few seconds. It may be forced to turn multiple times in succession. No matter, it will eventually attempt to turn back toward its best estimate of the original heading. In order to avoid digging into the sand and work with the motors' limitations, Donashello makes turns the way a car would if constrained to a small space, driving back and forth and turning small amounts with each pass.

Expectations for this project were to increase our knowledge and experience through collaborative work in robotics. On top of that, many people are getting robotics and automation, mechatronics, or engineering degrees and want to increase their hands-on expertise. The team also wanted to build the best robot it could. Due to the varying levels of experience, the team wanted to include many things that unfortunately did not make the final cut, such as a camera to record the path Donashello takes and a mapping function to record obstacles and paths. The expectations for the increased experience and teamwork skills in this project were met and exceeded. Everyone on this team learned a lot about collaborating on a big project like Donashello and gained specific skills in robotics and electronics. However, the team also gained experience in projects not coming to full expectations. The mapping function, wheels, and camera were all unable to be fully completed by the final test at the Great Sand Dunes. As sad as this is, it is a real aspect of projects like this and why many in the field of engineering and robotics get postponed or delayed. The team now has a better understanding of how these things happen and how to think on our feet and make the necessary changes to create a functioning rover in the time allotted.

Building Donashello was an absolutely amazing experience, and everyone on the team took away a lot of skills and knowledge, especially in teamwork and communication. Pumas In A Half-Shell learned that teamwork and communication are key to building any robot. You cannot complete something of this magnitude on your own; you have to rely on others and be reliable to cross the finish line. Overconfidence at the beginning of the design stage can be both a great thing as well as be problematic. The team had a lot of amazing ideas, but as the project came to its end, it hindered us as there was too little time to complete everything that was desired at first. Pumas In A Half-Shell needed to take the time to talk about everything that could be done, not the things that had already been completed, and prioritize the final projects.

Pumas In A Half-Shell gained many technical skills. Learning about the ways a robot runs on Arduino, how a motor shield works, and the programming it takes to make a robot do something as small as simply moving forward. What it takes to 3-D print even the most basic of objects using CAD software (Solidworks specifically), from the type of filament to the humidity of the room you are printing. How to solder and where things like soldering flux, solder wicks, solder suckers, and different gauges of solder are most effective. The team also increased different abilities like data analysis and basic graphic design. As well as abilities like electrical and mechanical troubleshooting, calibrating sensors, and design review. Many of us also developed the skills to achieve at least basic use of the Arduino coding language.

If this project were to continue, Pumas In A Half Shell has many recommendations as to the next steps for Donashello. Firstly, the wheels would be finished. They would be reprinted to the required diameter and width specifications, and the coupling and motor housing would be redone to accommodate those wheels. Another thing to add would be a sort of snow chain for the sand to add grip and weight to ensure traction and prevent the front wheel from lifting off the ground and causing digging in the sand. Next would be getting more powerful motors to increase the torque to account for the increased weight from the chains. Then the mapping function of Donashello's program would be finished, as well as the ability to store the maps separately for future review. A camera would also be a great addition to Donashello to allow the "astronauts" to have a visual feed of Donashello's path, which could then be stored in a similar way to the maps. Another thing to be added would be a suspension system. This would require a reworking of the chassis, leg, and shell design to accommodate it and would likely be the first thing needing to be tackled if it was added.

Donashello is an effective rover with an efficient design that is capable of basic navigation. Further improvements can be made, including edits to the wheels, programming, and motors; however, this is a project to take pride in. The multiple prototypes show the effort put into Donashello by Pumas In A Half-Shell, and the final product shows how far the team has come since this project started. The team learned much throughout the building process, including better usage of CAD software and 3-D printing abilities, better soldering skills, calibration skills, data analysis skills, and how to function in a team with many individual projects. Testing at the Great Sand Dunes will show the culmination of our work and push Donashello to his limit. Building Donashello increased the robotics and teamwork skills of everyone in the team, and moving forward, Donashello could become something truly incredible.