Individual Lab Report 5

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Team B: Space Jockey
with Brian Boyle, Ardya Dipta Nandaviri, Songjie Zhong

November 18th, 2013

1 Introduction

In the last two weeks, team B has continued working at a steady pace, and we are on track for our de-scoped fall validation test and should have a robot capable of traversing a horizontal surface soon. Depending on the results of our adhesive foot design, we may also be able to perform our traversal on a slanted or vertical surface by the fall validation redux in December. In the last two weeks, we have focused on prototyping and incremental improvement, with 3 passes of laser cut parts and rapid turnaround on our mechanical redesigns and improvements. This week, we were able to show the movement and calibration of our linear actuators during the progress report, and should be able to place those under ROS control in the next few days.

2 Individual Progress

My focus for the last two weeks has been working on the CAD model of our robot, making our laser cut runs, and ordering components. The full assembly (sans fasteners and linkages) may be seen in Figure 1.

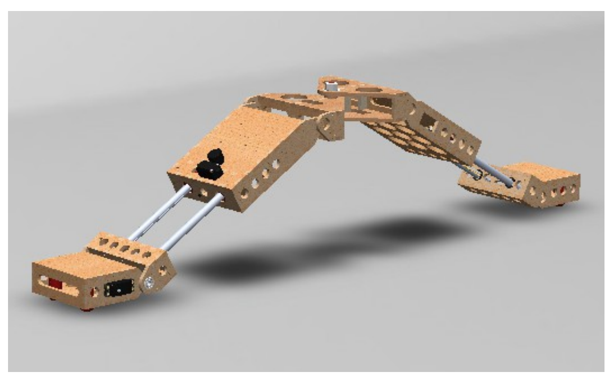

Figure 1: Completed Solidworks assembly of the Space Jockey robot, shown in mid-stride.

With each revision of the main chassis components, I lay out all of the laser cut components flat in Solidworks, exported the drawings to Inkscape, and fabricated all components on the Lasersaur in the Collaborative Machine Shop. The various part runs we made took about 1 hour each, but supplied us with tight-fitting, large scale parts much faster than we would be able to achieve with 3D printing or hand-machining.

After the parts were printed, Brian and I worked together to dry-fit all the components, and note any interference issues and other improvements that were necessary. One of the biggest changes that was made between revisions was the addition of lightening holes throughout the assembly. Although these holes do make our robot look a bit like mechanical Swiss cheese, we were able to shed over half a pound from the final assembly, which should lessen the strain on out rotary joint servos, and correspondingly decrease our power usage.

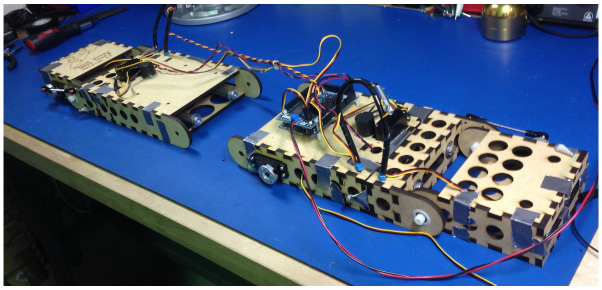

Figure 2: Image of the two dry-assembled linear segments and end effectors.

Photo courtesy Dipta Nandaviri.

For the progress review, I modified both of the servos for our linear actuators, assembled the components, and calibrated the feedback potentiometers. An arduino calibration script was then written that runs each actuator out to the end of its range, then slowly retracts the actuator until the inner limit switch is pressed. Once that is complete, it adds a pre-calculated software travel range to the minimum position, and then sends the actuator out to the end of its throw. Due to the tight component spacings surrounding the linear bearings I was unable to add a second limit switch at the far range of travel, but there is a software limit placed in 1/2” before the end, so we have a fair amount of safety margin before we risk burning up our motors.

Although this single-ended feedback approach is subject to some drift and variance in the mechanical motions, we found that the practical difference between our two actuators was less than ±1/32”, which is quite sufficient for our needs. A photo of the two assembled actuators can be seen in figure 2. Once we have completed revising and adjusting our chassis components, we will be permanently gluing the chassis together, which should further reduce slop in our mechanisms and provide a strong, permanent structure for our fall validation testing.

In the next week, we will be completing the mechanical construction of the entire robot, including the middle segment, which was missing at our progress review, and adding onboard ROS nodes to place the mechanical structure under the same control patterns that Brian has been developing in Rvis. If Songjie and Dipta are able to produce a good foot pattern, we will be fastening those onto the pre-fabricated foot mounting locations built into the chassis as well.

3 Challenges / Issues

This week, we overcame many challenges with our rapid prototyping and design iteration process. Many mechanical issues were encountered with the chassis design (tight or loose mechanical mates, slop in our feedback gearing mechanism, and linkage torque ratio problems), however, the rapid turnaround of our laser cut parts allowed us to quickly note and fix problems, and many issues were adjusted and corrected between revisions 1.1 and 1.3 (Which is the current hardware “release”).

On the software side, I did encounter two issues with our digital servo controls. First, when running the servos at their full 300 Hz update speed, we are having problems with them resetting or behaving improperly, I suspect that the higher current draws associated with the faster control responses may be triggering the current limiter of our benchtop power supply, but additional investigation is required. For the time being, we are simply running them as analog servos at 60 Hz, which will be able to perform fine if we are unable to fix this issue before our fall validation experiment.

The other issue encountered was that the digital servos we are using have a limited range of angular positions they will take. Unlike their analog counterparts, which will attempt to follow their control signals until physically restrained by their end stops, thus delivering ±90° of range, the digital servos we have will simply ignore any control signals outside of their factory programmed ±45° range. This is currently limiting the range of our rotary joints to ±23° (due to our 2:1 linkage ratios), which will be sufficient to perform our fall validation experiment on a flat surface, but will not allow us to perform the 90° plane change maneuvers we have specified for the Spring. This issue is not a permanent design flaw however, Hitec makes a programmer that should allow us to unlock the full range of our servos and adjust their accuracy as necessary. We have ordered one of these programmers, and should be able to correct this issue as soon as it arrives.

Our team's efforts in creating our adhesive foot mechanisms has continued to be delayed this week. We have encountered difficulties with our 3D printed components, with several test runs stopping midway or printing incorrectly. We have also not been able to successfully cast an effective V-10 pad on the bottom of our foot. The best method employed to date can be seen in Figure 3. This approach uses individual sized dams attached to each foot pad to provide a casting reservoir for the V-10 material. However, this method does not produce consistent pad heights across the foot, and the circular foot pads do not provide sufficient attachment force to support our robot. We will continue to iterate on this design, however, if it is not successful by the fall validation experiment, we will simply do our test on a horizontal surface, as discussed in previous ILRs.

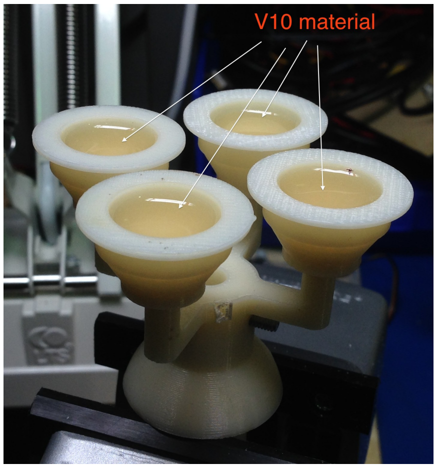

Figure 3: Current V-10 casting approach.
Photo courtesy Dipta Nandaviri.

4 Efforts By Team Members

This week, Brian helped me with the final assembly and tuning of the linear actuators, as well as adding gait and step generation functionality to the GUI. Although the current implementation is limited, it is providing a valid gait pattern to the necessary ROS topics, so we should be able to add a listening node to the Arduino, and have full robot control from the GUI before our validation experiment.

Songjie continued to iterate on the adhesive foot pad design, and has finalized the compliant ball joint design we will be using in the “ankle” segments of the robot. These spring-loaded ball joints will allow the flush-mounted feet of the robot to adhere to irregular or curved surfaces, and transform some of the shearing force applied to the mechanism into a normal force on each individual pad.

Dipta helped Sonjie with the foot pad casting this week, but had been unable to continue any further with the power distribution board until we received component parts from Digikey earlier today.

5 Future Plans

For team B, the immediate future is obvious: we will continue to assemble and test all components of the robot to be prepared for the fall validation experiment next Monday. Brian and I will be integrating the hardware and software under ROS control. Songjie will be manufacturing the ball-joints for the design, and iterating on our foot mechanism, although we may use a non-adhesive stand-in for the validation experiment. Dipta will be assembling and testing the power board, and will be helping with the wiring and testing of our robot. We've got a lot of work to do, but we're well on track for success.