Investigating Swing Foot Trajectory for Stair-terrain on Humanoid Robots

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USC Viterbi School of Engineering

SHINE Summer High School Intensive in Next-Generation Engineering

Introduction

This summer I worked in Professor Nguyen's lab focusing on robotics control systems. The project I worked on while I was in the lab was investigating foot placement trajectories for mobile bipedal robots by using Bézier curves. The goal of my project was to make the robot be able to step up a box in a simulation by adjusting the swing foot trajectory. My Ph.D. mentor and I also worked on implementing current control frameworks on bipedal robot hardware.

Figure 1: The Bipedal Robot Posing. (Picture taken by Dylan)

Problem

The problem we came across was the robot would constantly hit its foot on the side of the box because its foot wouldn't get enough height to clear the box. The solution we came up with uses Bézier curves instead of a quadratic curve for swing foot trajectory. We used specifically a cubic Bézier curve because it allows for more control of the shape of the curve. This allows us to move the leg back before to tries to move forward giving the robot more time to lift its leg so it doesn't get caught on the side of the box. This also gives us much more precise control of the curve.

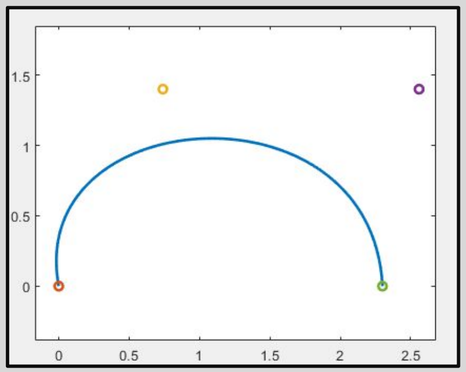

Figure 2: The Bézier curve we would be using in the simulations. The colored points are the control points used to calculate the curve.

Results

We input the Bézier curve into the swing foot Cartesian-space PD controller to allow the swing foot to follow our desired trajectory. After implementing the Bézier curve into the simulation, we started by trying to see if it could have a stable walking gait. After some tests, we were able to get a very stable walk that could be adjusted to make the strides taller or longer.

Our next step was to try stepping up a block. The original parameters from walking on a flat surface wouldn't work so I had to fine-tune the control points of the curve as well as adjust the endpoint of the curve higher to match the height of the step. Finally made it so that after the robot makes it up the block, it returns to the original parameters from when it could walk stably.

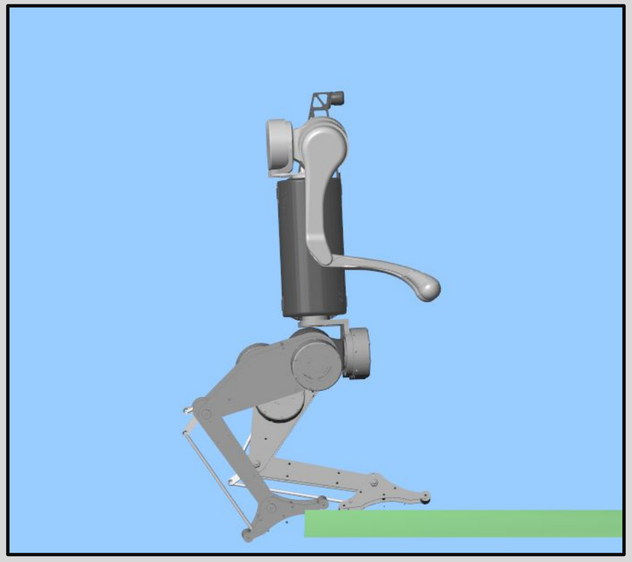

Figure 3: The Bipedal Robot stepping up a block 5 cm in height

Skills Learned

I learned how to use MatLab to write scripts that would graph large amounts of data to help troubleshoot problems. The script I wrote would take a long text file and output graphs corresponding to each value such as motor angle, the center of mass, and foot location. This helped us troubleshoot any problems with the robot.

Figure 5: The Bipedal Robot's wiring. (Picture taken by Dylan)

I learned the basics of hardware operation and maintenance. We had to open up the bipedal robot to re-solder the wires connecting the motors on the legs to the board inside the robot. After that, we cable managed the outside of the robot to make sure there are no malfunctions.

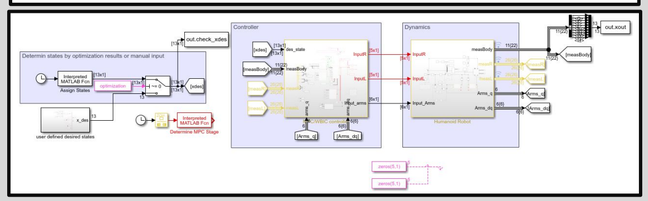

Figure 6: Bipedal simulation diagram in Simulink.

I learned how to optimize the controls of a bipedal robot in MATLAB. I had to change the swing of the robot's leg from being a quadratic curve to something more versatile. After some research, I concluded that a Bézier curve would be the best for climbing up steps. I first created a Bézier curve in a test file. Then after that, I implemented the Bézier curve from the text file to the main simulation and fine-tuned it until it could work.

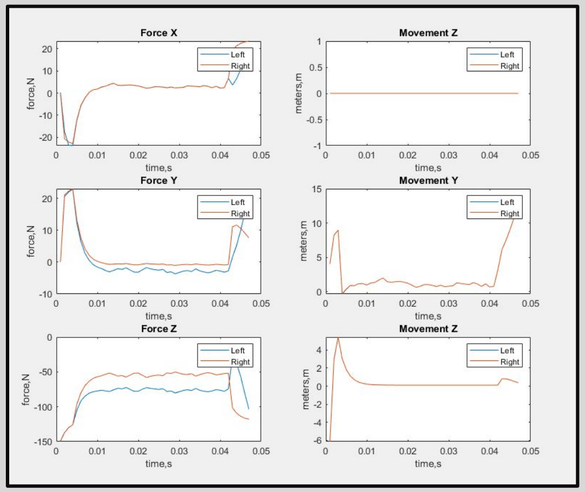

Figure 4: Graphs based on the force and movement values from the feet of the robot.

Next Steps for Me

The next step for me is to start and become the president of the robotics club at my school. I can apply the skills I learned from working on this research project to my next project working in the robotics club. I will also be able to teach the other members of the club the things I learned.

Acknowledgements

I would like to thank Professor Nguyen for allowing me to work in his lab this summer. I would also like to thank my mentor Junheng and my center mentor Marcus for inspiring me and helping me along the way. Finally, I would like to thank Dr. Mills and everyone else who helped me in Shine.