Ranger Walking Initiation

Stephanie Schneider
sns74@cornell.edu
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Abstract

I joined the Biorobotics Lab this semester to gain experience with an application of my two main fields of interest: mechanical engineering and computer science. My project goal was ultimately to design and implement walking initiation, from standing still, for the Cornell Ranger. Since I was new to the lab this semester, I spent the first month or so learning how to work with the Ranger itself as well as the software behind it. After obtaining a thorough understanding of the tools at my disposal, I could begin progress towards my primary goal. My final design was successful; given good initial conditions, Ranger was able to independently switch from standing still to steady-state walking in all five trials that were performed. There are still many potential areas of improvement, both for the current program design, and also to increase functionality.

Training

The first couple weeks after I joined the lab, Matt helped me get accustomed to the general theory and procedures I would be using to work with Ranger. He explained the configuration of Ranger's code, how to upload a new program onto the robot, the procedure for creating system variables, etc. I learned how to use Labview, and completed some C++ tutorials outside of lab, both of which were new to me this semester. As far as robotics theory, he also explained the basics of PID control and finite state machines. To make sure I understood the FSMs I would be working with, he recommended I make diagrams for the hip and each foot, which served as a useful reference all semester (Figure A-1).

To familiarize myself with the Ranger's FSM structure, I modified several different conditions to induce a change of state. A FSM is comprised of a finite number of states and the transitions between them, each transition corresponding to a list of conditions. The conditions in this case involved different parameters that would be useful later: timing, pressure sensors in the feet, and hip angle. A sample FSM I constructed is included in Figure A-2 In this FSM, the transitions are dependent on the hip angle; the range of each state is shown in the diagram. Each state displayed a different colored LED to verify changes.

Initial Attempts

I first began working on my project of walking initiation about a month after I joined the lab. Matt shared the progress he had made, and explained how he envisioned it working: his idea was to have Ranger rock back and forth several times (the program is called "Rock Mode" for this reason), starting with the outer foot forward. Each time the front foot pushed hard enough to lift it off the ground, the hip would swing freely, decreasing its angle. After several cycles, Ranger would be in a good position and have enough momentum to swing the inner foot forward and begin walking (Figure A-3).

This was the plan of attack for a large portion of time: make small adjustments to the rocking pattern and get Ranger in an appropriate position to begin walking. I tried many combinations of different independent variables (a compiled list is included in Table A-4), but for all of them, Ranger rocked unstably back and forth, and never made any real progress. The biggest flaw with this concept was its unnecessary complexity. Depending on the pressure sensors in the feet proved to be difficult, as they weren't accurate in either foot's push state, and timing such a complicated sequence was unreasonable.

In contrast, the next design was greatly simplified. Ranger's inner foot started behind; it pushed strongly, then cleared immediately, such that it could swing forward right away instead of rocking first. This caused Ranger to fall straight back. Logically, putting the inner foot forward and repeating the same process could have been successful. This technique proved very effective in gaining forward momentum, but only so that Ranger was simply tipping forward, instead of translating its center of mass.

Results

The final design combines these two ideas of cyclic rocking and one hard push. The inner foot (which starts behind) is given a small push from the front foot, causing Ranger to lean back. Then, when Ranger begins to tip forward again, the inner foot pushes strongly, allowing it to swing forward in just the right way needed for walking. Conditions for state transitions are dependent on timers throughout. A diagram of the final design is included in Figure A-5.

Discussion

The final design is successful because it applies a strong push to an existing forward momentum, created by the slight rocking. These two factors combine to produce a motion similar to how walk mode was previously initiated. A major advantage to this method was its simplicity, compared to the original design. Syncing every movement together relied entirely on timing. Finding the exact timing for the transfer of weight involved a bit of guesswork, which was manageable for one push, but would have been exceedingly difficult in the original cyclic rocking design.

The final adjustment in this design, which previously worked about one in five tries, was the initial offset of the foot angles. After tweaking all other aspects of the design, Ranger was failing mainly because it pivoted from its feet as it moved forward, causing it to lean severely by the time the inner foot swung forward. This problem was solved by having Ranger initially leaning back, that is, by giving the feet initially larger angles. After these small modifications, the program ran reliably every time, as demonstrated in the video.

One significant issue with all of the designs, including the final design, is a requirement of ideal initial conditions. Ranger has to be extremely still, with its weight evenly distributed, to work properly. If these conditions are not set up correctly, a single version of the program yields a variety of different results, namely Ranger losing balance and falling over.

Future Work

Several improvements could be implemented in the future to make this function more smooth and reliable. There are already timers specific to each individual state, so a simple modification could make the program less dependent on the overall rocking timer, increasing flexibility in the code. A more substantial extension involves initiation of rock mode: currently, when rock mode begins, Rangers enters a “wait period” of five seconds, after which it will start rocking whether or not it has been set up properly. Ideally, the timer would not start until given some signal, possibly a button on the remote control, or at least until both feet are on the ground. Lastly, any improvement to Ranger’s stability throughout the process would enhance reliability. This could be accomplished through the use of sensors that detect variability in the initial set up so Ranger can adjust its stance accordingly.

Conclusion

Overall, the knowledge gained about robotics was my greatest accomplishment while working in the lab. In the beginning, I relied heavily on a trial-and-error technique, but even in this short time, I began to approach the problem in a more analytical way. For example, I started using Labview as a debugging tool more often. I also became open to trying different overall designs instead of just making small adjustments and expecting them to work. My biggest regret is only committing one credit’s worth of time to this project. If I had allotted more time for the Ranger, I could have implemented some of my suggested improvements. I also could have potentially installed GPS, or some of the other ideas Matt and I discussed initially. I realize that I am still extremely novice in the area, but I am grateful for the experience I've gained and I believe it is the first step of a potential career path.

APPENDIX

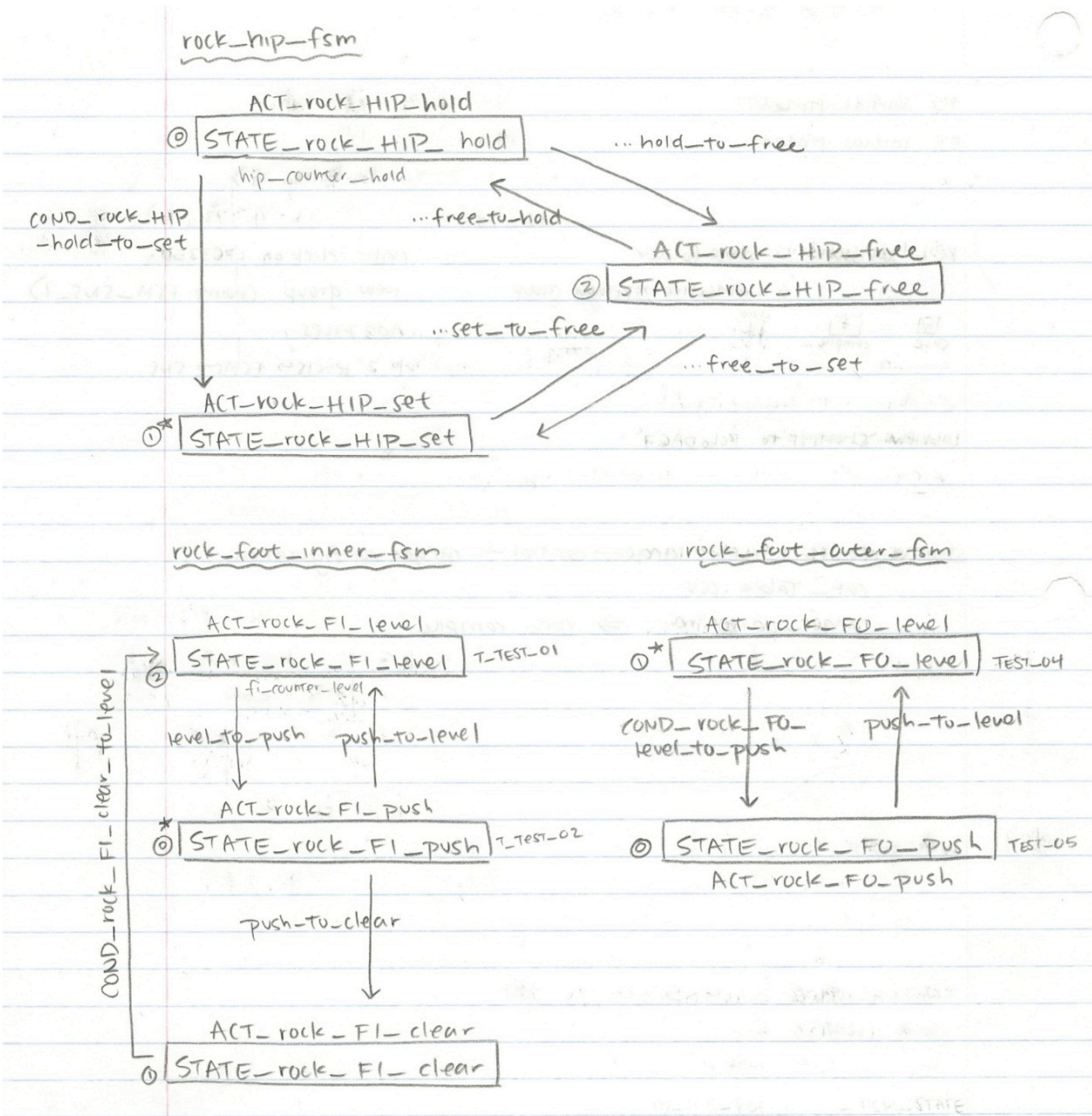

Figure A-1: Diagram of Finite State Machines, Rock Mode

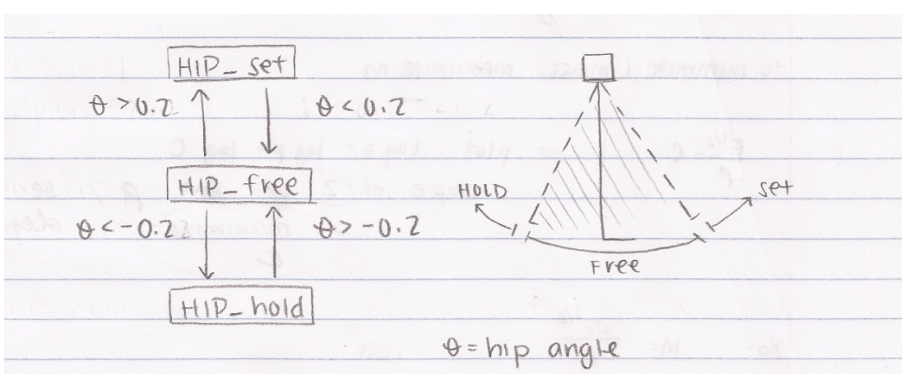

Figure A-2: Diagram of Sample Finite State Machine

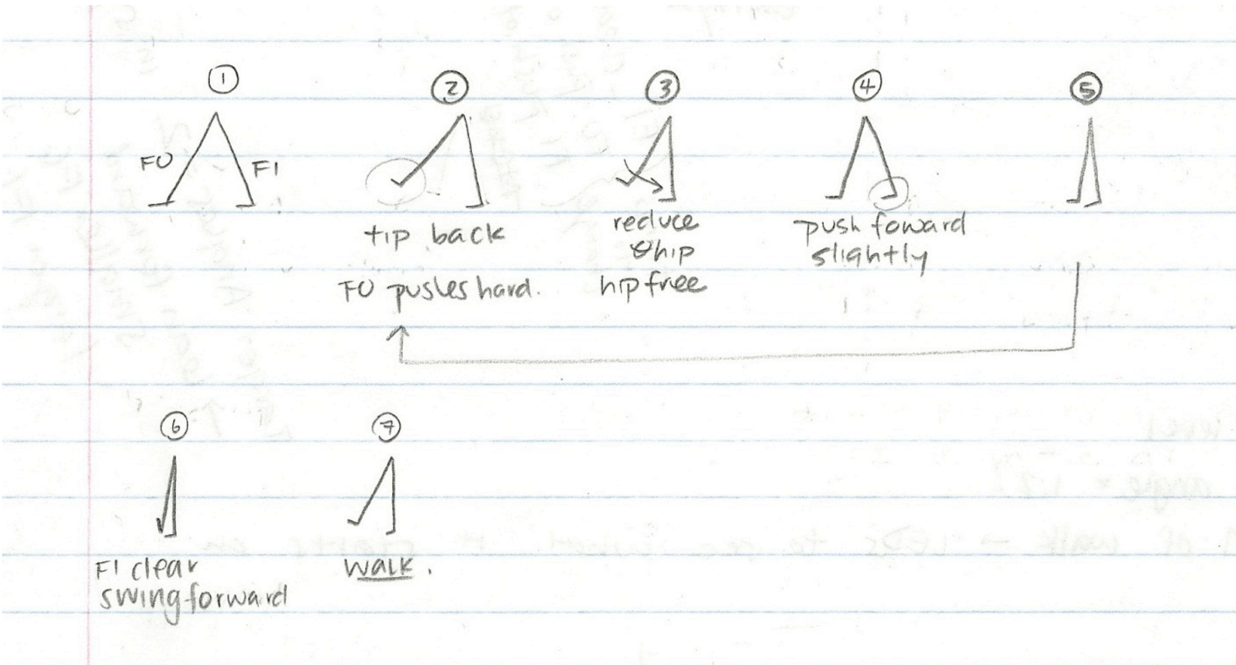

Figure A-3: Initial Design of Rock Mode

Target angle for inner foot
Target angle for outer foot
Initial hip angle
Initial foot angles
Timing
Kp – stiffness constant (did not change)
Sensor values (did not change)

Table A-4: List of Independent Parameters. This table contains a list of all possible variables that were changed to modify Ranger's motion. Typically, changes were made in small increments, and independently, so as to isolate cause and effect.

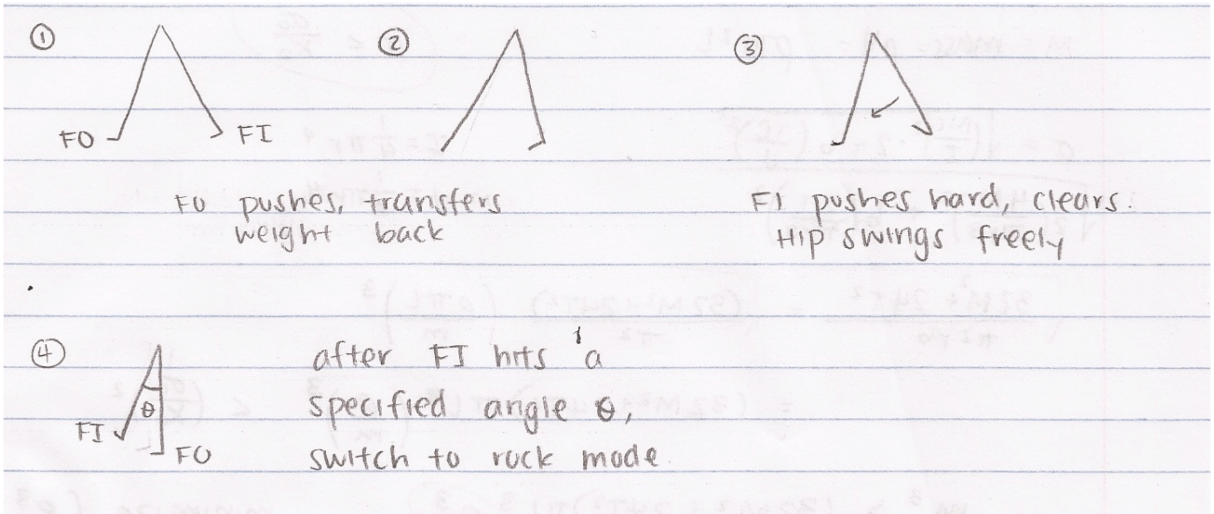

Figure A-5: Final Design of Rock Model

Variable Name	Value	Description
P_R_FO_KP	20	Stiffness constant, outer foot
P_R_FI_KP	20	Stiffness constant, inner foot
P_R_FO_PUSH_OFFSET	0.5	Angle below nominal
P_R_FI_PUSH_OFFSET	0.85	Angle below nominal
P_R_FI_CLEAR_OFFSET	1.5	Angle above nominal
P_R_FO_TANG	2.0	Target angle
P_R_FI_TANG	2.0	Target angle
P_R_FO_INIT_ANGLE	2.2	Initial angle
P_R_FI_INIT_ANGLE	2.2	Initial angle
P_R_FO_END_ANGLE	2.0	Not-initial angle
P_R_FI_END_ANGLE	2.0	Not-initial angle
P_R_H_THRESHOLD_ANGLE	1.6	Hip angle required to switch to walk mode
P_R_CONTACT_THRESHOLD	1000	Pressure value when Ranger is on the ground
P_R_ROCK_TIMER	0	Rock mode timer
P_R_WAIT_TIME	5000	Time to wait before rocking, in milliseconds
P_R_FI_PUSH_TIMER	700	Time the inner foot is in push state
P_R_FO_PUSH_TIMER	800	Time the outer foot is in push state
P_R_ROCK_TO_WALK	0	Boolean value, true switches to Walk

Table A-6: List of State Variables Created