CMPEN 497 – Humanoid Robotics

Project 4
Simulated Motion Design

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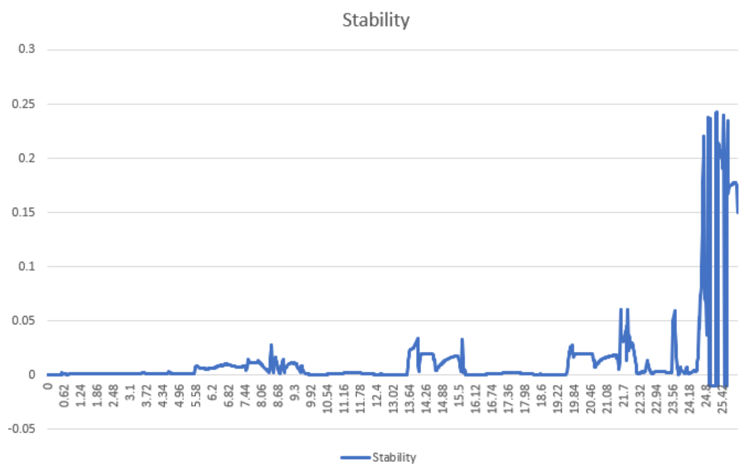
Problem 1

Stability Analysis

Stability is calculated by comparing the center of mass(CoM) of the robot with respect to its center of pressure (CoP). The center of mass is a point in space where the robot's mass is perfectly balance and center of pressure is the point where all dynamic forces that acts on the robot are perfectly balanced.

Based on the code provided by Addison, the com to cop script reads the CSV file that contains times, CoM and CoP data value when the robot is being simulated on Webots. Then, the function calculates the distance between CoM and CoP for every second using the function 'getdist()' , which calculate the distance between two points in 3D space. If a CoP data for a certain time step is missing, the code assumes the robot has fallen and assign stability value of 0.01.

Figure 1: Figure of Webots Simulation



Based on the graph plotted for the stability values vs time, we can see that the robot is stable before it starts falling after 24.18 seconds. where the stability metric has riven from the low peak of 0.01 to 0.23 and oscillates for 2 seconds as the fall involves in multiple drastic angle changes for the servo motors. During 5.58 seconds to 9.3 seconds, a slight increase in stability metric was observed as the robot has slight lifted the right leg and spreaded out the legs while most part of the base are still with contact with the ground. Thus, the center of pressure is still within a close promity with the center of mass of the robot. During 13.52 seconds to 15.6 seconds, another stability metric value spike was observed as the robot started to lift its Left ankle partially and goes back to an upright posture with 100% contact with the floor as observed on 15.6 seconds. Similiarly, the robot had the same mirror move on its right ankle on 19.22 seconds and a spike on stability metric value was observed and settles down at 23.22 second as it starts on another move. The final move had incorporated a drastic move on both the robot's left and right hip and thus we can see a sudden spike of 0.05 around 23.56seconds as the robot spread its hip and waves its arms drastically and the set of actions might had cause some damping and oscillation forces on the robot's base. Finally, the drop move required multiple joints of the robot to rotate at least 10 degree and thus the user Fan Han Hoon had designed the robot to had a knell drop to reduce the impact of the robot falling on the table.The entire leg of the robot was tuned to drop in a way where the lower part of the legs will turn to an angle where it acts as a cushion for the robot upon falling and reduces the impact of the coutneracting forces against the robot. Thus, the intended damping action had resulted in a massive spike of 0.24 in stability metric value and observed in the final moments of the robot during the simulations. The remaining parts where little to no stability metric value changes were observed as the robot was only doing waving motions or spining around. Since the arms does not had a huge impact on the overall center of mass and center of pressure, the impact to the stability is minimal and the values does match the predicted outcomes.

Problem 2

Writeup

Instructions
Project 4 was mainly about utilizing the program that was provided by TA Addison. On CMPEN 497 canvas page, started code with pressure sensors and scripts required for processing data were provided. Before designing the task, user Fan Han Hoon had reviewed the instructions provied in the project 4 description pdf and project 4 instructions for after dance pdf. A table of motor constraints were provided in the documents and it is pivitol for the project as it provides the concept of how to mirror the moves and ensuring the users are editing the moves based on the physical capability of the servo motor of the robot.

In the project 4 starter code, a list of files such as worlds, output, controller, sample motions, and stability calculation scripts were provided. Initially, Webots 2021a was utilized to intiate the preset world that was provided for project 4. After opening the world, I would load one of the provided sample dance motion text file and delete all the preset dance.Then, I would set the simulation to void to test out different actions and figure out the respective value to achieve it by monitoring the values shown in the rotational motor sensor. It was then followed by a lengthy testing and design phase as i try out difference values to achieve the moves that I enjoyed.

After completing the dance move, I would build the simulation world again with my dance motion file being called out in the code. Since it was running well, I rebuilt the file again and start the video recording of the simulation. In the project 4 world's script, I could also define the location and name of all the output files for CoM, CoP and recordings. Once all the recordings were completed, I contiune by running the provided python scripts of raw to CoP(computes Cop from the raw pressure data collected), com to CoP (Computes CoM to CoP Stability), plot pressure (creates a video showing the foot pressure sensors, CoM, CoP and BoS throughout the simulation) and merge video (which merge the simulation recordings and foot pressure video output from plot pressure script.). During this phase, it is important to check all the codes to ensure that it was reading the data from the correct file and output as the filename and location that we defined.

Dance Concept
The dance design concept was to mainly test out how damping of the arms and legs of the robot affects the stability. The null hypothesis for the design is the arms would have greater impact on the stability while the alternate hypothesis is the legs wold have greater impact on the robot's stability. The aim for the design is to reject the null hypothesis and prove that the legs woulds have a greater impact on the stability as it was acting as the structure support for the robot. Besides that, I am also testing to see if the damping actions of the arms would affects the overall stability.

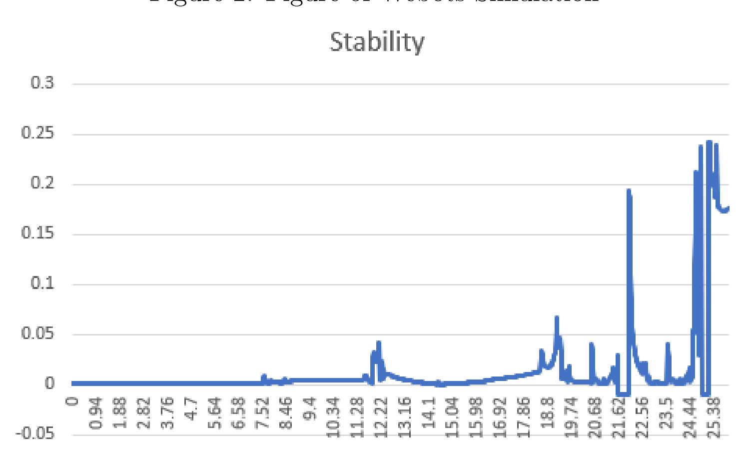
Challenges
The constraints provided in the document has restricted certain moves where I wanted to swing the arms 180 degrees but any arm motion that swings to the back side of the robot would exceed the lower boundary of 0 as it was determined to be a negative rotational motor value. Besides that, I had no experience on dance and thus I had to rely on my knowledge on gif, ads and reveiwing music animation to get some inspiration. The biggest challenge of all is the time constraint of the project. The limited amount of time provided for

the project had also overlapped with project 3 and some of my midterms and other project courses, thus I had to sacrifice some concepts that I initially planned.

Problem 3

Extra Credit

Figure 2: Figure of Webots Simulation



The extra credit dance is inspired by the presentation that was organized on Wednesday.The difference between this dance versus my initial dance is that i added more movement to the hip and base of the robot and started the dance with the robot looking around. Based on the simulated video and the graph plotted for the stability values vs time, we can see that once again, the head and arm movement of the robot had little effect on the overall stability of the robot.However, as the robot starts to knell forward around 7.52seconds, both of the robot legs had moved forward and backwards respectively and causes the change of the base of support (BoS) to transform into a diagonal shape. During the phase of change, we can observed the minor rise of the value of the stabiliy by 0.01. As the robot remains on the same lean forward motion, the movement of the head does not affects the stability of the robot. The next stability value spike was observed at 11.28 seconds as the robot returns back to an upright position with its arms hanging and legs spreading into a diagonal BoS again. As the robot slowly move its knee joints with some simple arm movements, we can see that it reduces the stability of the robot and the shape of the BoS slowly changes to a more rectangular shape and return back to the diagonal shape due to the base movements. Based on the comparison of the simulation and the sensor plot, we can find out that a rectangular or square BoS has higher stability than the diagonal BoS as it has more surface of contact to evenly spread out the CoM. Eventually, the robot repeat a similiar move that was presented in the HoonFanHan.motion and spreaded out the robot's legs drastically. During the movement transition, the BoS was stretched out of the viewing box as it spreads its legs close to the ground but mainting the CoP relative to the CoM's position had kept the robot stable despote of the spike in the values on stability. Finally, when the fall occured, the CoP had went far away from the CoM and unable to balance out the weight, thus it results in frontal right fall with a massive spike in the stability value.

References

[1] ”Petro, Addison (2023,April).Project 4 Information,https://psu.instructure.com/courses/2231401/pages/project-4-information?module$_i tem_i d = 38320095.CMPN497.StateCollege.$”