Ecole Centrale de Nantes

Humanoid Robots Report Lab 3

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1 Introduction

The goal of this laboratory is to model a compass-walking robot walking with, similarly to the first and lab, but this time with active gait and optimal trajectory. It is possible to run the program by using the "*optimwalk.m*" file. The robot is considered in single support, but then the second leg swings and performs an active step. Contrary to the Figure below, the robot is not on a slope but on a plane, and the legs have active torques. The known quantities are:

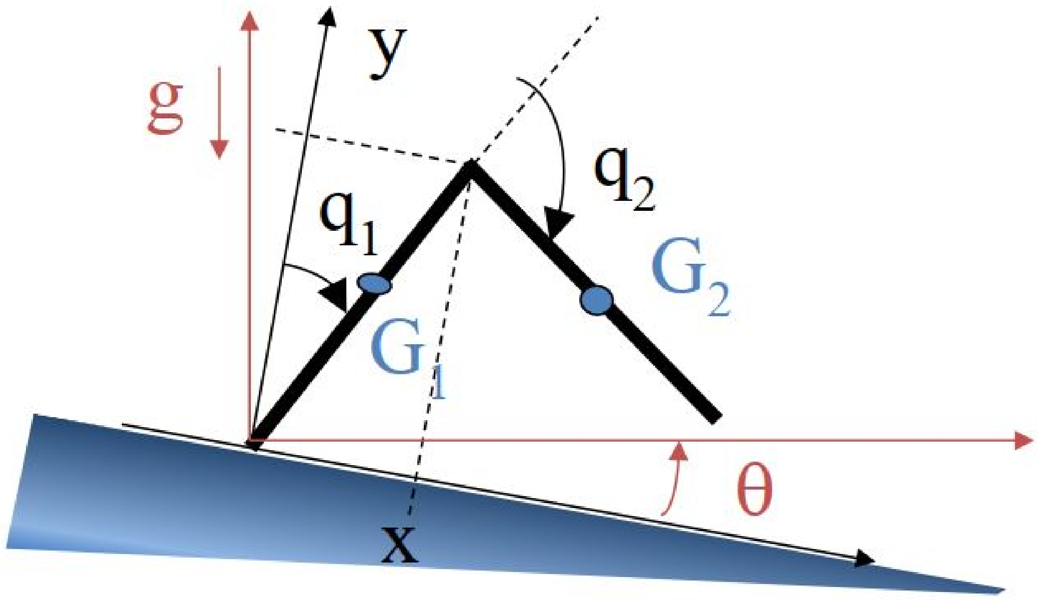

Figure 1: Compass Robot

- Link Length $l = 0.8m$
- Link Mass $m = 2kg$
- Inertia $I = 0.1kgm^2$
- Center of Mass (G1, G2)
- distance from the hip $S = 0.5m$
- Gravity $g = 0.8m * s^{-1}$
- Slope Angle $\theta = rad$

In this report, we present the steps followed to obtain the required results and visualization implemented with **MATLAB** files. In this lab, the created dynamic model of the robot in single support, the reaction force model, the impact model, the relabel equation and the plot function of lab 1 and 2 have been reused.

2 Simulation of the Active Gait

The simulation is done by finding various components of the active model. Trajectories are defined for the swing leg and they are optimized with the use of the function *fmincon*. The initial conditions were set as:

$$\begin{bmatrix} q_{1initial} \\ q_{1intermediate} \\ q_{2intermediate} \\ \dot{q}_{1initial} \\ \dot{q}_{2initial} \end{bmatrix} = \begin{bmatrix} -0.2rd \\ 0rd \\ -\pi \\ 0rd/s \\ 0rd/s \end{bmatrix} \tag{1}$$

with a time period set to $T = 1$, and the time of the intermediate step as $T_{intermediate} = T/2$. This was later fed to he optimization function. These conditions were stacked in a vector called $Jsolcon0$. The function $fmincon$ uses a couple of already defined functions, namely "$resol$", for finding the solution to the function and "$constraint$", where the constraints have been set.
The impact model is found, via the equation 2:

$$\begin{bmatrix} A_1 & J_R^T \\ J_R^T & A_1 \end{bmatrix} \begin{bmatrix} \dot{x}^+ \\ \dot{y}^+ \\ \dot{q}_1^+ \\ \dot{q}_2^+ \\ I_{R_{2x}} \\ I_{R_{2y}} \end{bmatrix} = \begin{bmatrix} A_1 \\ 0_{2x4} \end{bmatrix} \begin{bmatrix} \dot{x^-} \\ \dot{y^-} \\ \dot{q}_1^- \\ \dot{q}_2^- \end{bmatrix} \tag{2}$$

Then, the torques can be found according to our dynamic model, as shown in equation **??**:

$$\tau_i = A(q_i)\ddot{q}_i + H(q_i, \dot{q}_i + G(q_i) \tag{3}$$

with A as the Inertia matrix of the biped robot, H the Coriolis matrix and G the gravitational effect matrices. Lastly, we can find the Ground Reaction R by using:

$$R_i = 2m(\ddot{q}_i - g) \tag{4}$$

where $m$is the mass of a single leg, and g the gravitational effects. These equations we reused from lab one. In "$resol.m$" we set the criteria and the constraints (taken on the < 0 side of the equation) and the cost function of the walking, as described in function 5:

$$C = \frac{1}{L_{step}} \sum_{k}^{N=100} \tau_i^2 \delta \tag{5}$$

The last step was to find the trajectories tha the two legs should follow: this was done by defining a set of of points, $traj_i\_points$ with the same structure as $Jsolcon0$, and then use the polynomial trajectory structure of:

$$traj_i\_points = K \begin{bmatrix} a_{0i} \\ a_{1i} \\ a_{2i} \\ a_{3i} \\ a_{4i} \end{bmatrix} \tag{6}$$

with $K = poly\_matrix$ in our code, and equal to:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0.5T^4 & 0.5T^3 & 0.5T^2 & 0.5T & 1 \\ T^4 & T^3 & T^2 & T & 1 \\ 4T^3 & 4T^2 & 2T & 1 & 0 \end{bmatrix} \tag{7}$$

This way it is possible to find the trajectory equation for each joint, 1 and 2, by using this equation and its coefficients, extracted from 6. The profiles of the trajectory equation, simply derived by the above equations, are:

$$\begin{bmatrix} q_i \\ \dot{q}_i \\ \ddot{q}_i \end{bmatrix} = K \begin{bmatrix} a_{0i} + a_{1i}t + a_{2i}t^2 + a_{3i}t^3 + a_{4i}t^4 \\ a_{1i} + 2a_{2i}t + 3a_{3i}t^2 + 4a_{4i}t^3 \\ 2a_{2i} + 6a_{3i}t + 12a_{4i}t^2 \end{bmatrix} \tag{8}$$

Finally, with the constraints defined as global in "*constraints.m*" as in the assignment, it is possible have the program run. However, unfortunately, the trajectory found makes the swing leg perform a rotation around itself, and does not ultimately output a valid optimal step. It is possible to see the animation through the "*animation.m*" function. Some problems where encountered while designing the best solution possible to respect the constraints. By trial and error and changing the initial parameters or by changing the step length or the period, $fmincon$ seems unable to find a proper solution. Unfortunately the results seem disappointing and far from expected. A proper design could be achieved, with a bit more guidance and if the labs were actually done at the universtity and not remotely, but unfortunatelly this was not possible.

3 Variable Outline

Then, we provide an outline and profile of the meaningful variables of the laboratory. Below, it is possible to see the two optimal trajectories, q_1 and q_2. As we can see, q_1 performs properly, but q_2 diverges from its properly expected sinusoidal behaviour and cycle.

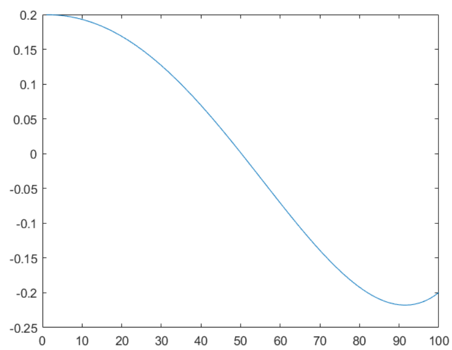

Figure 2: q1

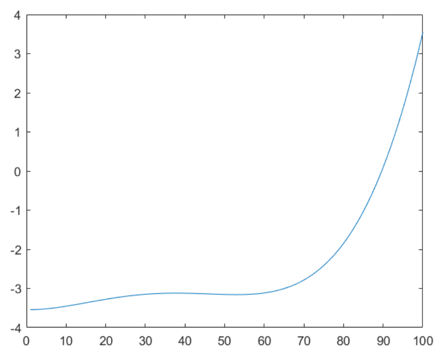

Figure 3: q2

Below, it is possible to see the two torques trajectories, tau_1 and tau_2. As we can see, tau_1 performs properly, but tau_2 diverges exponential as well. This shows us that the second trajectory should be corrected but unfortunately it was not possible to find a solution despite the efforts.

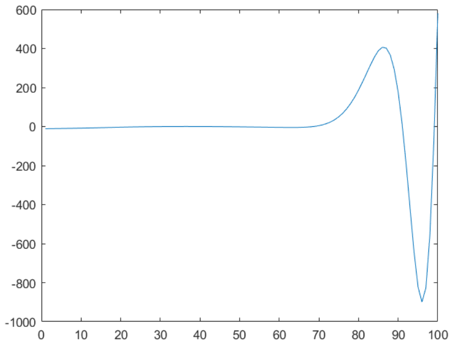

Figure 4: Torque Leg 1

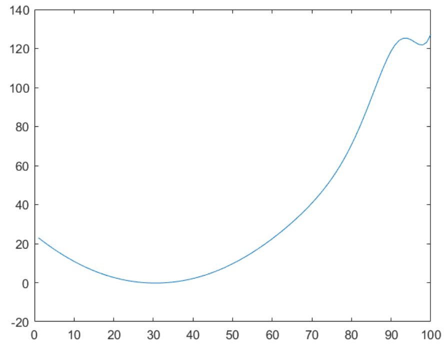

Figure 5: Torque Leg 2

From the variable outlines we clearly see that trajectory for q_1 is well-behaved, as it starts and ends at the same point, maintaining cyclicity, while the trajectory for the second leg is unbouded and is not cyclic, creating the above-mentioned issues in the development of the lab.