Rehabilitation Robotics
Project Report

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Introduction

Partial loss of hip, knee and ankle function is very common in elderly people, stroke sufferers and people with spinal cord injuries. This causes geriatric disorders, physical disabilities and locomotion challenges.[1] Lower limbs are very important since we use them in all everyday activities. Hence, an injury to them is considered to be urgent. An exoskeleton robot provides active, programmable and controllable therapeutic assistance to patients with neuromotor deficiencies. [2]

Leg exoskeletons are used in rehabilitation. Rehabilitation exoskeletons can lessen the strain on physical therapists of stroke survivors, as it offers greater repeatability and quantitative measures of improvements [3]. While designing leg exoskeletons for stroke survivors many aspects need to be considered including the limb sensitivity and comfort for the user.

Another application of the leg exoskeleton is load carrying augmentation. This is mostly used for soldiers in the military. It reduces the load on the leg when carrying heavy backpacks and walking for large amounts of time.[4]

The project had two parts

a. Computing torques for simulating movement of the leg based on a desired motion.
b. Simulating the motion of the leg depending on the torques

The leg exoskeleton was modelled using the Newton-Euler inverse dynamics algorithm and coded on MATLAB. The model was simulated using Working model 2D.

Methods

The Leg exoskeleton was built considering my own leg as reference. The upper leg(hip), the lower leg(calf) and the foot were modelled as cylinders and the links were considered to be motors. The desired movement for the leg was given and the torques were computed using the Newton-Euler method of outward-inward recursion (inverse dynamics). Inverse dynamics is the ca1culation of the forces required at a robot's joints in order to produce a given set of joint accelerations. The principal uses of inverse dynamics are in robot control and trajectory planning.

Computation of torque

The torques were computed using the Newton-Euler inverse dynamics method. This algorithm basically forms dynamic equations written separately for each link. The equations are recursive.

Building simulation

The leg exoskeleton was modelled on Working model 2D. The hip, calf and ankle were modelled as rectangles. They were connected to each other using motors which could be controlled using the rotational angle values or torque values. The mass of each limb was equal to sum of the mass of the leg and exoskeleton. The center of mass was computed by considering the exoskeleton to be a point mass at the proximal end of the limb. The moment of inertia was computed considering the limbs to be cylinders. All these assumptions were considered for the purpose of modelling. A screenshot of the working model simulation is presented in Figure 1.

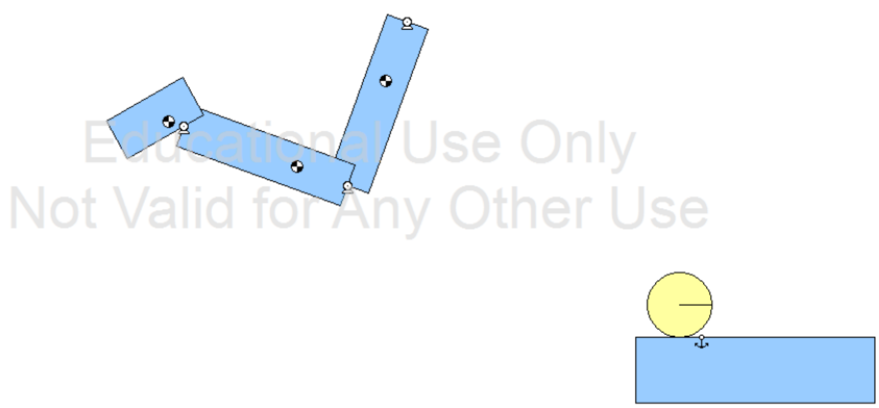

Figure 1: Screenshot of the simulation

Results

The results on running the simulation are presented below.

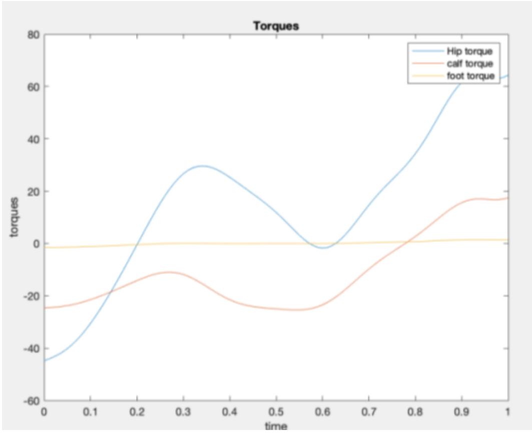

Figure 2: Joint torques vs time

Figure 2 shows the plot for the computed joint torques vs time. The hip torque values are large because it needs to support the complete exoskeleton. The figure was plotted for one second.

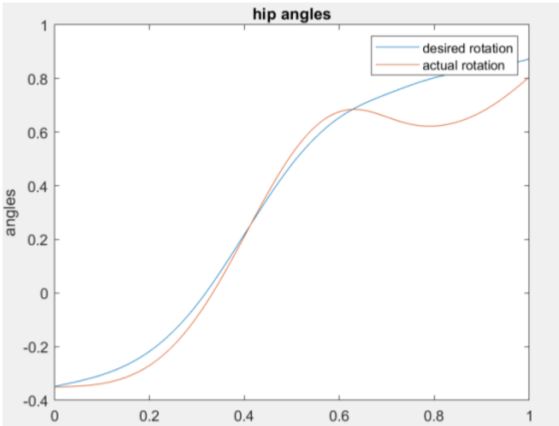

Figure 3: Computed and desired hip angles vs time

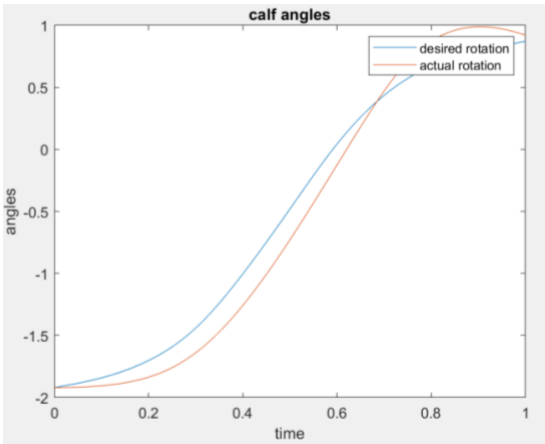

Figure 4: Computed and desired knee angles vs time

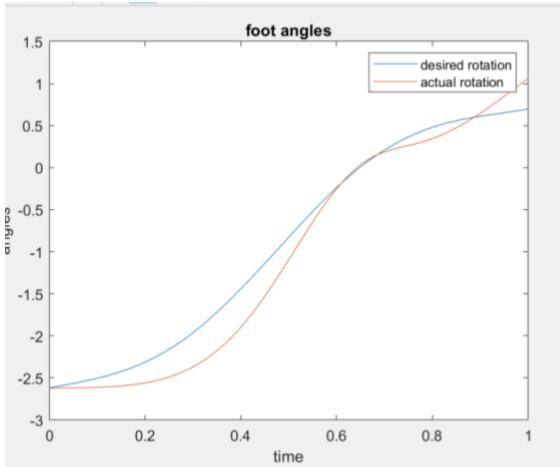

Figure 5: Computed and desired ankle angles vs time

Table 1: Mean square error of the joint angles

Joint angles	Mean square error
Hip	0.0076
Knee	0.0295
Ankle	0.059

The computed angles for the hip, knee and ankle are presented in Figure 3,4,5. These values are found to be very close to the desired values. The actual values as the ones given to the recursive algorithm. The values were plotted for one second. The mean square error for the hip were computed considering the actual and the desired values of the obtained data. They are presented in the Table 1.

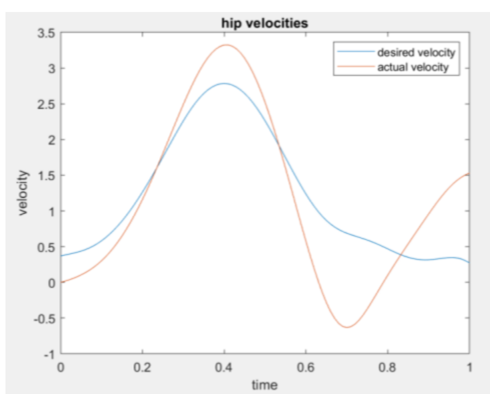

Figure 6: Computed and desired hip velocities vs time

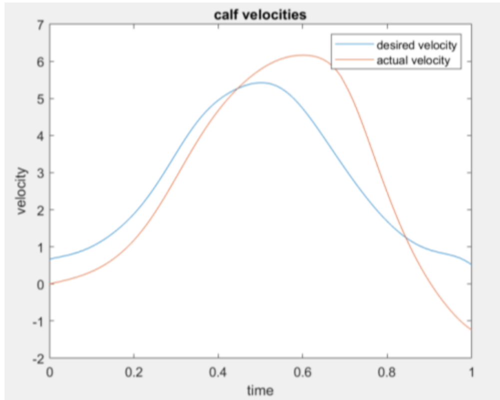

Figure 7: Computed and desired knee velocities vs time

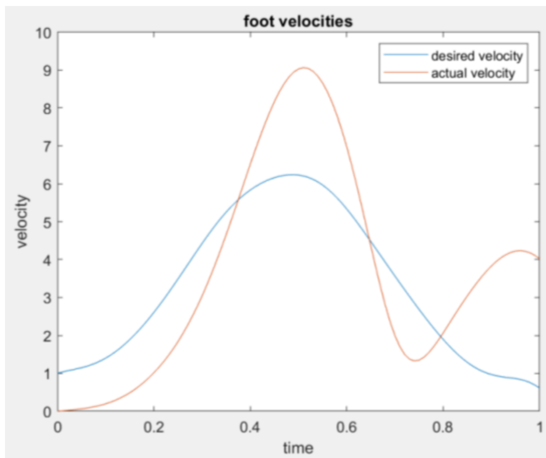

Figure 8: Computed and desired ankle velocities vs time

Table 2: Mean square error of the joint velocities

Joint velocities	Mean square error
Hip	0.6976
Knee	1.204
Ankle	3.412

The velocities for the links are presented in Figure 6,7,8 These values are very close to the desired values but there is a slight error. This is mostly because of the limitations of the model. The mean square error for the velocities is presented in Table 2

Discussion

The results obtained were very close to the actual values of the rotation and velocities. The mean square errors for the rotations and velocities were low. It was observed that the mean square error was highest for the ankle joint. This is expected because an error in the hip and knee joint would affect the ankle joint.

The model has many limitations. Some of the limitations are discussed below.

a. The structure of the leg

   The leg was modelled as cylinders. The actual leg is not really a cylinder. Hence, the model is an ideal representation of a very complex structure which is difficult to model.

b. The mass of the leg and exoskeleton

   The mass of the leg is not evenly distributed. Considering the mass to be a point mass at the proximal end is idealistic and needs to be corrected when the model to be built in real life.

c. Velocities

   The actual velocity depends on a lot of environmental factors like air friction etc. These need to be considered during modelling as well.

In the project we basically model the lower limb and prove the Newton-Euler inverse dynamics algorithm. There are many applications of this exoskeleton in rehabilitation and military. The future scope is to model the leg more accurately by taking exact values of the parameters. And to build the exoskeleton. But this has its own problems. The challenges surrounding exoskeleton technology are selection of actuators, power supply consideration, mechanical design, human-exoskeleton interface and control method. These still need to be looked at and studied.

References

[1]Sciencedirect.com. (2019). Exoskeleton (Robotics) - an overview | ScienceDirect Topics. [online] Available at: https://www.sciencedirect.com/topics/engineering/exoskeleton-robotics [Accessed 9 Dec. 2019].

[2]Geonea, I., Dumitru, N., Rinderu, P., & Margine, A. (2018). Design Solutions for Human Legs Motion Assistance Exoskeletons. In Proceedings of the World Congress on Engineering (Vol. 2, pp. 4-6).

[3]Walsh, Conor James, et al. “A Quasi-Passive Leg Exoskeleton For Load-Carrying

Augmentation." International Journal of Humanoid Robotics, vol. 04, no. 03, 2007, pp. 487–506., doi:10.1142/s0219843607001126-soldier

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